105th Congress, 1st Session – – – – – – – – – – – – House Document No. 105–144

BEACH NOURISHMENT PROJECT

COMMUNICATION

FROM

THE ACTING ASSISTANT SECRETARY (CIVIL WORKS), THE DEPARTMENT OF THE ARMY

TRANSMITTING

A REPORT ON THE STORM DAMAGE REDUCTION AND SHORELINE PROTECTION PROJECT FOR REHOBOTH BEACH AND DEWEY BEACH, DELAWARE, PURSUANT TO SECTION 101(b)(6) OF THE WATER RESOURCES DEVELOPMENT ACT OF 1996

OCTOBER 6, 1997.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed.

U.S. GOVERNMENT PRINTING OFFICE

43–884 WASHINGTON : 1997

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(Only Appendices D and E printed)

LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

REPLY TO ATTENTION OF

30 SEP 1997

Honorable Newt Gingrich
Speaker of the House
of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

Section 101(b)(6) of the Water Resources Development Act of 1996, authorized a storm damage reduction and shoreline protection project for Rehoboth Beach and Dewey Beach, Delaware. However, since the project is a beach nourishment project located in a recreation and tourist area, and involves a long-term, 50-year Federal investment beyond initial construction, the project would receive a low budget priority. Therefore, in view of the current constrained budget situation, it is not likely that funding for this project will be included in future budget requests.

The project is described in the report of the Chief of Engineers dated December 23, 1996, which includes other pertinent reports and comments. These reports are submitted in partial response to a resolution adopted by the Senate Committee on Environment and Public Works on June 23, 1988. The views and comments of the State of Delaware, the Department of the Interior, and the Environmental Protection Agency are set forth in the enclosed reports.

The authorized project extends from the northern end of Rehoboth Beach to the southern border of Dewey Beach, a distance of about 2.6 miles. Along the shoreline of Rehoboth Beach, the plan includes a 125-foot-wide beach berm at an elevation of +8 feet National Geodetic Vertical Datum (NGVD), and a 25-foot-wide storm dune at an elevation of +14 feet NGVD. Along the shoreline of Dewey Beach, the project includes a 150-foot-wide beach berm at an elevation of +8 NGVD, and a 25-foot-wide storm dune at an elevation of +14 feet NGVD. The plan also includes dune grass planting, sand dune fencing, vehicle access ramps, and dune walkovers. Additionally, the project includes advance beach fill and periodic renourishment to ensure the integrity of the design. The plan requires the placement of about 1,437,000 cubic yards of initial beach fill to be obtained from a nearby offshore borrow site, and subsequent future periodic nourishment of about 360,000 cubic yards every three years for 50 years. The project design includes features to minimize adverse environmental impacts. No separable fish and wildlife mitigation is required.

Based on October 1995 price levels, the total first cost of the project is estimated at about $9,115,000, with a Federal first cost of about $5,925,000, and a non-Federal first cost of about $3,190,000. In accordance with WRDA 1986, cost sharing is based on shoreline ownership, extent and type of shoreline development, and extent of public benefits and public access in the project area. The total cost of future periodic nourishment is estimated at about $59,320,000, which would be spent over a 50-year period.

The Office of Management and Budget advises that there is no objection to the submission of this report to the Congress for information. A copy of its letter is enclosed in the report.

Sincerely,

John H. Zirschky
Acting Assistant Secretary of the Army
(Civil Works)

Enclosure

CRC: (w/o enclosure)
CECW-AR
CECW-PE
Office of Management and Budget (ATTN: Rick Mertens)
SACW: Read, Sign, File
SACW: Dola
Prepared: Zoltan Montvai/CWCW-PE/Sep 19, 97

COMMENTS OF THE OFFICE OF MANAGEMENT AND BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

AUG 1 1997

The Honorable John H. Zirschky
Acting Assistant Secretary of the
Army for Civil Works
Pentagon - Room 2E570
Washington, D.C. 20310-0108

Dear Dr. Zirschky:

As required by Executive Order 12322, we have completed our review of former Assistant Secretary Lancaster's recommendation for the report of the Delaware Coast, from Cape Henlopen to Fenwick, Rehoboth and Dewey Beaches.

The recommendation for this project in his letter of April 8, 1997, is consistent with the policies and program of the President. The Office of Management and Budget does not object to submission of this report to Congress.

Sincerely,

Kathleen Peroff

Kathleen Peroff
Deputy Associate Director
Energy and Science Division

COMMENT OF THE STATE OF DELAWARE

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
89 KINGS HIGHWAY
P.O BOX 1401
DOVER DELAWARE 19903

OFFICE OF THE SECRETARY

TELEPHONE (302) 739 - 4403
FAX (302) 739 - 6242

November 14, 1996

Mr. James Warren
Policy Review Branch
Policy Review and Analysis Division
ATTN: CECW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

Dear Mr. Warren:

The Department of Natural Resources and Environmental Control has reviewed the final environmental impact statement on the Delaware Coast from Cape Henlopen to Fenwick, Delaware -- Rehoboth Beach/Dewey Beach Interim.

Delaware has invested a considerable amount of resources in bringing this project to this point. The Philadelphia District of the Army Corps of Engineers has pursued an interactive process in developing this document and furthering this project which can be characterized as a collaborative approach. The result has been a full exchange of information and preferences which affords us the opportunity to fully endorse both this report and the beach nourishment project which it describes. We feel that this project will protect an area of very high economic importance to the State of Delaware. Additionally, our citizens will be afforded protection from storm damage which has in the past proved dangerous and even fatal. We agree that the described environmental impacts are minimal and are prepared to review actual plans preparatory to permit application.

It is our intention to continue funding through the construction and maintenance phase and we look forward to working with the Corps on the collegial basis which has characterized our relationship in the past.

Sincerely,

Christophe A.G. Tulou
Secretary

pc: Mrs. Francine Booth

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

NOV 6 1996

ER 95/796

Mr. David B. Sanford, Jr.
Chief, Policy Review and Analysis Division
Policy Review Branch
ATTN: CECW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

Dear Mr. Sanford:

The Department of the Interior has completed its review of the proposed Chief of Engineers report and related documents for Rehoboth Beach/Dewey Beach; Delaware Coast from Cape Henlopen to Fenwick Island, Sussex County, Delaware.

We have no comments on the report and do not object to the proposed project.

Sincerely,

Willie R. Taylor

Willie R. Taylor
Director, Office of Environmental
Policy and Compliance

COMMENTS OF THE ENVIRONMENTAL PROTECTION AGENCY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION III

841 Chestnut Building

Philadelphia, Pennsylvania 19107-4431

NOV 0 6 1996

Mr. Robert McIntyre
Policy Review Branch
Policy Review and Analysis Division
ATTN: CECW-AR (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3861

RE: Rehoboth/Dewey Beach Interim Feasibility Study/ Final Environmental Impact Statement (FEIS)

Dear Mr. McIntyre:

The Environmental Protection Agency has reviewed the responses to comments on the above referenced document that was completed in accordance with the National Environmental Policy Act (NEPA). Based on our review, we have no further comments on the project.

Thank you for the opportunity to comment. The contact for this project is Danielle Algazi. She can be reached at (215) 566-2722.

Sincerely,

Roy E. Denmark

Roy E. Denmark, Jr.,
NEPA Program Manager

Celebrating 25 Years of Environmental Progress

REHOBOTH AND DEWEY BEACHES

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

23 DEC 1996

CECW-PE (10-1-7a)

SUBJECT: Delaware Coast from Cape Henlopen to Fenwick, Delaware - Rehoboth Beach/Dewey Beach Interim

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on the study of hurricane and storm damage reduction for Rehoboth Beach and Dewey Beach, Sussex County, Delaware. It is accompanied by the report of the district and division engineers. These reports are in partial response to a resolution by the Committee on Environment and Public Works of the United States Senate dated 23 June 1988. This resolution requested review of the Delaware Coast from Kitts Hummock to Fenwick Island, Delaware, report to determine if additional beach erosion control, hurricane protection, and improvements for related purposes are advisable.

2. Section 101(b)(6) of the Water Resources Development Act of 1996 (WRDA 1996), Public Law 104-303, authorized construction of the Rehoboth Beach and Dewey Beach, Delaware, project for storm damage reduction and shoreline project subject to completion of a final report of the Corps of Engineers on or before December 31, 1996 and subject to the conditions recommended in that final report. This report constitutes the final report of the Corps of Engineers required by WRDA 1996.

3. The plan developed by the district engineer consists of one continuous project, from the northern end of Rehoboth Beach to the southern border of Dewey Beach, a distance of 13,500 linear feet. Along Rehoboth Beach, the plan provides for a 125-foot-wide beach berm at elevation +8 feet National Geodetic Vertical Datum (NGVD) and a dune at elevation +14 feet NGVD. The dune would have a crest width of 25 feet. At Dewey Beach, the project would transition to a 150-foot-wide beach berm at elevation +8 NGVD and have a dune at elevation +14 feet NGVD. The dune crest width would be 25 feet. The plan also includes appurtenant project features such as dune grass planting, sand dune fencing, vehicle access ramps, and dune walkovers. Additionally, the plan includes advance beach fill during the initial construction and periodic nourishment and project monitoring for 50 years after completion of the initial construction. No environmental mitigation features are proposed.

4. As reported by the district engineer, based on October 1995 price levels, the total first cost of the plan is estimated at $9,114,000. Under cost sharing specified by the Water Resources Development Act of 1986, $5,924,000 of the total first cost of the plan would be Federal and $3,190,000 would be non-Federal. Of the non-Federal share, the total cash

contribution required would be $2,975,000. The balance of the non-Federal share of first cost would consist of $215,000 for the estimated creditable cost for lands, easements, rights-of-way, relocations, and suitable borrow and dredged or excavated material disposal areas. Periodic renourishment costs would be shared as continuing construction. The total cost of periodic renourishment is estimated as $59,321,000, allocated $38,559,000 Federal and $20,762,000 non-Federal, at the October 1995 price level. Based on a discount rate of 7.625 percent and a 50-year period of economic analysis, average annual periodic renourishment costs are estimated as $728,100 Federal and $392,100 non-Federal. Costs associated with periodic monitoring activities, currently estimated at $1,000,000 over the 50-year economic life of the project, as identified in the operations and maintenance manual developed by the district engineer, will be borne by the non-Federal sponsor. The ultimate project cost, including initial construction, periodic renourishment, and project monitoring is estimated as $70,756,000, allocated $45,342,000 Federal (64.1 percent) and $25,414,000 non-Federal (35.9 percent), at the October 1995 price level. Total average annual benefits are estimated at $3,476,000, and average annual costs are estimated at $1,988,000. Equivalent annual net benefits are estimated at $1,488,000. The resulting ratio of benefits-to-costs is 1.7. Based on information available at this time, the plan developed by the district engineer is the national economic development plan.

5. I generally concur in the findings of the reporting officers. The plan developed is technically sound, economically justified, and socially and environmentally acceptable. The plan conforms with essential elements of the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies and complies with other Administration and legislative policies and guidelines on project development. However, based on current budget priorities, projects like Rehoboth Beach/Dewey Beach, Delaware, would receive a low budget priority and it is unlikely that funding for this project will be included in future budget requests.

6. However, in light of the authorization provided by Section 101(b)(6) of WRDA 1996, should the project receive construction appropriations for Federal implementation, it would be implemented subject to the cost-sharing and other applicable requirements for hurricane and storm damage reduction projects as established by WRDA 1986, as amended, and would be implemented with such modifications as the Chief of Engineers deems advisable within his discretionary authority. Further, Section 101(b)(6) of WRDA 1996 cited project costs from earlier information provided by the Corps of Engineers. Those costs have been adjusted to reflect current information on the project authorized by Section 101(b)(6) of WRDA 1996. Paragraph 4 of this document contains the current

information. Federal implementation would also be subject to the non-Federal sponsor agreeing to comply with applicable Federal laws and policies and that it shall be responsible for the following items of local cooperation:

a. Provide 35 percent of total project costs assigned to hurricane and storm damage reduction and as further specified below:

(1) Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or ensure the performance of all relocations determined by the Federal Government to be necessary for the initial construction, periodic nourishment, operation, and maintenance of the project.

(2) Provide all improvements required on lands, easements, and rights-of-way to enable the proper disposal of dredged or excavated material associated with the initial construction, periodic nourishment, operation, and maintenance of the project. Such improvements may include, but are not necessarily limited to, retaining dikes, waste weirs, bulkheads, embankments, monitoring features, stilling basins, and dewatering pumps and pipes.

(3) Provide during construction any additional amounts as are necessary to make its total contribution equal to 35 percent of total project costs assigned to hurricane and storm damage reduction.

b. For so long as the project remains authorized, operate, maintain, monitor, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Federal Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government.

c. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor, now or hereafter, owns or controls for access to the project for the purpose of inspection, and, if necessary, after failure, to perform by the non-Federal sponsor, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project. No completion, operation, maintenance, repair, replacement, or rehabilitation by the Federal Government shall relieve the non-Federal sponsor of responsibility to meet the non-Federal sponsor's obligations, or to preclude the Federal Government from pursuing any other remedy at law or equity to ensure faithful performance.

d. Hold and save the United States free from all damages arising from the initial construction, periodic nourishment, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterments, except for damages due to the fault or negligence of the United States or its contractors.

e. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20.

f. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended, 42 U.S.C. 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for the initial construction, periodic nourishment, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction.

g. Assume complete financial responsibility, as between the Federal Government and the non-Federal sponsor for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the initial construction, periodic nourishment, operation, or maintenance of the project.

h. As between the Federal Government and the non-Federal sponsor, the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability. To the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

i. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for the initial construction, periodic nourishment, operation, and maintenance of the project, including those necessary for relocations, borrow materials, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

j. Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army."

k. Provide 35 percent of that portion of total historic preservation mitigation and data recovery costs attributable to hurricane and storm damage reduction that are in excess of 1 percent of the total amount authorized to be appropriated for hurricane and storm damage reduction.

l. Participate in and comply with applicable Federal floodplain management and flood insurance programs in accordance with Section 402 of Public Law 99-662, as amended.

m. Within one year after the date of signing a project cooperation agreement, prepare a floodplain management plan designed to reduce the impact of future flood events in the project area. The plan shall be prepared in accordance with guidelines developed by the Secretary of the Army and must be implemented not later than 1 year after completion of construction of the project.

n. Prescribe and enforce regulations to prevent obstruction of or encroachment on the project that would reduce the level of protection it affords or that would hinder operation and maintenance of the project.

o. Not less than once each year, inform affected interests of the extent of protection afforded by the project.

p. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in preventing unwise future development in the floodplain, and in adopting such regulations as may be necessary to prevent unwise future development and to ensure compatibility with protection levels provided by the project.

q. For so long as the project remains authorized, the non-Federal sponsor shall ensure continued conditions of public ownership and use of the shore upon which the amount of Federal participation is based.

r. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

JOE N. BALLARD
Lieutenant General, USA
Chief of Engineers

ADDENDUM
REVISED BENEFIT-COST COMPARISON FOR THE NED PLAN
FOR THE DELAWARE COAST FROM CAPE HENLOPEN
TO FENWICK ISLAND- REHOBOTH BEACH/DEWEY BEACH
INTERIM FEASIBILITY STUDY

Discount Rate	7.625%
Project Life	50 years
Price Level	October 1995
Base Year	2000

Benefits:	
Storm Damage Reduction	$ 2,573,000
Reduced Maintenance	$ 29,000
Recreation	$ 844,000
Benefits During Construction	$ 30,000
Total Average Annual Benefits	$ 3,476,000

Costs:	
Initial Construction Costs	$ 9,114,000
Interest During Construction (Revised)	$ 685,000
Real Estate Costs	$ 215,000
Total Periodic Nourishment (50 yrs)*	$59,321,000
Total Project Monitoring (Revised)**	$ 2,321,000
Total Average Annual Costs	$ 2,004,000

Benefit-Cost Ratio	1.7
Net Benefits	$ 1,472,000
Ultimate Project Cost***	$70,756,000

*Includes Major Replacement Costs

**Includes O&M monitoring efforts estimated at $20,000 annually ($1,000,000 total), which will be the responsibility of the non-Federal sponsor.

***The ultimate project cost including initial construction, periodic nourishment and project monitoring is currently estimated at $70,756,000, allocated $45,342,000 Federal (64.1%) and $25,414,000 non-Federal (35.9%)

DELAWARE COAST FROM
CAPE HENLOPEN TO FENWICK ISLAND-
REHOBOTH BEACH/DEWEY BEACH
INTERIM FEASIBILITY STUDY

SYLLABUS

This report presents the results of a feasibility phase study to determine an implementable solution and the extent of Federal participation in a storm damage reduction project for the towns of Rehoboth Beach and Dewey Beach, Delaware. This feasibility study was prepared based on the recommendations of the reconnaissance study completed in 1991, which identified a possible solution to the storm damage problems facing the Rehoboth Beach/Dewey Beach area. The reconnaissance study also determined that such a solution was in the Federal interest and identified the non-Federal sponsor. The feasibility study was cost shared between the Federal Government and the State of Delaware through the Delaware Department of Natural Resources and Environmental Control (DNREC), and was conducted under the provisions of the Feasibility Cost Sharing Agreement executed in May 1992. The feasibility study was initiated in June 1992 upon receipt of study funds.

The Rehoboth Beach/Dewey Beach area stretches for approximately 2 miles along the northern part of the Atlantic Ocean coast of Delaware. The area has been subject to major flooding, erosion and wave attack during storms, causing damage to structures, and, since 1992, twice resulting in the Rehoboth Beach/Dewey Beach area being declared a National Disaster Area by the President of the United States. In recent years, continued erosion has resulted in a reduction of the height and width of the beachfront, including the virtual destruction of the existing dune system, which has increased the potential for storm damage.

The feasibility study, evaluated various alternative plans of improvement formulated on hurricane and storm damage reduction. The NED plan identified for Rehoboth Beach is a 125-foot wide berm with an elevation of +8 ft NGVD, and a dune with an elevation of +14 ft NGVD and for Dewey Beach a 150-foot wide berm with an elevation of +8 ft NGVD, and a dune with an elevation of +14 ft NGVD. The selected plans include dune grass, dune fencing and suitable advance beachfill and periodic nourishment to ensure the integrity of the design. The plan requires 1,437,272 cubic yards of initial fill to be placed from a designated offshore borrow site and subsequent periodic nourishment of 360,000 cubic yards every three years for 50 years.

The feasibility report is based on October 1995 price levels and the Federal interest rate of 7.625%. The economic analysis for the selected plan indicates that the proposed plan will provide annual benefits of $3,476,000 which when compared to annual cost of the proposed plan of $1,966,000, yields a benefit to cost ratio of 1.8 with $1,510,000 in net excess benefits.

The total initial project cost of construction is currently estimated to be $9,114,000 (at October 1995 price levels). The Federal share of this first cost is $5,924,000 (65 percent), and the non-Federal share $3,190,000 (35 percent). Periodic nourishment is estimated at $3,638,000 on a three year cycle and will be similarly cost shared for the life of the project.

DESCRIPTION OF THE SELECTED PLAN
FOR THE DELAWARE COAST
FROM CAPE HENLOPEN TO FENWICK ISLAND

REHOBOTH BEACH/DEWEY BEACH
INTERIM FEASIBILITY STUDY

Project Title: Delaware Coast from Cape Henlopen to Fenwick Island; Rehoboth Beach/Dewey Beach Interim Feasibility Study

Description: The proposed project provides a protective beach with a dune system to reduce the potential for storm damage in the towns of Rehoboth Beach and Dewey Beach, DE.

Beach Fill	
Volume of Initial Fill	1,437,272 yd
Volume of Renourishment Fill	360,000 yd
Interval of Renourishment	3 years
Length of Fill	13,500 l.f.
Width of Beach Berm (Rehoboth Beach)	125 ft.
Width of Beach Berm (Dewey Beach)	150 ft.
Width of Dune Crest (Rehoboth Beach through Dewey Beach)	25 ft.
Elevations	
Dune Crest	+14 ft NGVD
Beach Berm	+8 ft NGVD
Slopes	
Dune (Landward)	1V:5H
Dune (Seaward)	1V:5H
Beach Berm to Existing Bottom	1V:15H
Dune Appurtenances	Grass Planting Sand Fencing Vehicle Access Dune Walkovers
Price Level	October 1995
Project Cost	
Initial Cost	$9,114,000
Annualized (Discounted)	7.625%
Cost Apportionment (First Cost)	
Federal	$5,924,000
Non-Federal	$3,190,000
Average Annual Benefits	
Storm Damage Reduction	$2,573,000
Recreation	$ 844,000
Benefit/Cost Ratio	1.8

NOTE: All elevations referenced to the National Geodetic Vertical Datum (NGVD).

INTRODUCTION

1. The Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study is an ongoing study of the shore protection problems facing the entire ocean coast of Delaware. Due mainly to fiscal limitations on the part of the non-federal sponsor, the Delaware Department of Natural Resources and Environmental Control (DNREC), the feasibility study was broken up into three interim studies staggered in time and covered by one overall Feasibility Cost Sharing Agreement (FCSA). The three interim studies and their respective durations include Rehoboth Beach/Dewey Beach (1992-1995), Bethany Beach/South Bethany (1995-1998) and Fenwick Island (1997-2000).

2. This feasibility report for the Rehoboth Beach/Dewey Beach interim feasibility study will provide recommendations for future actions and programs to reduce storm damage and shoreline erosion as well as provide valuable information to coastal planners and engineers. This feasibility report presents the existing conditions, without-project analysis, plan formulation analysis and the National Economic Development Plan (NED) plan for this first interim study of the Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study.

3. This document was prepared in accordance with ER 1105-2-100 (Civil Works Planning Guidance Notebook), ER 1110-2-1150 (Engineering & Design for Civil Works Projects), ER 1165-2-130 (Federal Participation in Shore Protection) and other applicable guidance and regulations. The guidelines for planning water and related land resources activities as contained in the Civil Works Planning Guidance Notebook, require that Federal water resources activities be planned for achieving the National Economic Development (NED) objective. The NED objective is to increase the value of the Nation's output of goods and services and improve national economic efficiency, consistent with protecting the Nation's environments pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements.

4. Due to the level of detail included in the engineering appendix, and the fact that the proposed project is not complex, a General Design Memorandum (GDM) should not be required. Therefore, it is expected that this study will progress directly into the Plans and Specifications (P&S) phase.

STUDY AUTHORITY

5. The Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study is being conducted in response to a resolution adopted by the U. S. Senate Committee on Environment and Public Works on 23 June 1988 at the request of Senator William Roth, Jr. This resolution reads as follows:

> "RESOLVED BY THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS OF THE UNITED STATES SENATE, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby requested to review the report on the Delaware

Coast from Kitts Hummock to Fenwick Island, Delaware, published as House Document Number 85-216, and other reports, with a view to determining the advisability of providing improvements in the interest of beach erosion control, hurricane protection, and related purposes, along the Delaware Coast from Cape Henlopen to Fenwick Island. Included in this study will be the development of a physical and engineering data base on coastal area changes and processes, including appropriate monitoring during development of the data base, as the basis for actions to prevent the harmful effects of shoreline erosion and storm damage."

STUDY PURPOSE AND SCOPE

6. The purpose of the feasibility study is to evaluate an array of solutions to reduce storm damages, including shoreline protection measures, and if warranted, to select a plan and economically optimize the scale of design. If such a plan is supported by the non-Federal sponsor and is environmentally and socially acceptable, the feasibility report would recommend an implementable solution for hurricane and storm damage reduction (H+SDR) for the area under study.

7. This interim feasibility study covers the towns of Rehoboth Beach and Dewey Beach and considers the restoration and protection of the shoreline from erosion and storm damage. This report considers the results of the reconnaissance phase of this study and includes the results of additional analyses conducted during the feasibility phase. In addition to the plan recommended in the reconnaissance phase, the feasibility study considered a wide array of alternatives for comparison. The scope of this interim study includes an overview analysis of the entire Delaware ocean coast to gain an understanding of processes to better assess and analyze problems at Rehoboth Beach and Dewey Beach. However, the principal focus of this interim study is on the problems associated with the persistent erosion and storm damage potential along the shoreline of Rehoboth Beach and Dewey Beach which has caused significant economic losses during past storm events.

8. Field data collection efforts included in this study consist of offshore acoustic impedance surveys to identify potential offshore borrow areas; hydrographic and topographic surveys; the deployment of a directional wave gage to determine the wave climate off the coast of the study area; benthic sampling of the identified offshore borrow source; remote magnetometer surveys of the identified offshore borrow site to investigate the presence of cultural resources; sand samples from the beaches in Rehoboth Beach and Dewey Beach; and vibracore samples from the identified offshore borrow source. Field investigations and office work involved analysis of the collected field data and other data pertinent to the storm damage problems facing Rehoboth Beach and Dewey Beach.

This feasibility report will:

a. Provide a complete presentation of the existing conditions, without-project analysis and plan formulation analysis for the Rehoboth Beach/Dewey Beach interim feasibility study;

b. Indicate compliance with applicable statutes, executive orders and policies; and

c. Provide a sound and documented basis for decision makers at all levels to judge the recommended solutions.

9. This report includes detailed engineering and economic appendices, including cost estimates, to compare alternative plans of protection. Ultimately the goal of this study is to identify the National Economic Development Plan (NED) to reduce the hurricane and storm damage potential in the towns of Rehoboth Beach and Dewey Beach.

DESCRIPTION OF THE STUDY AREA

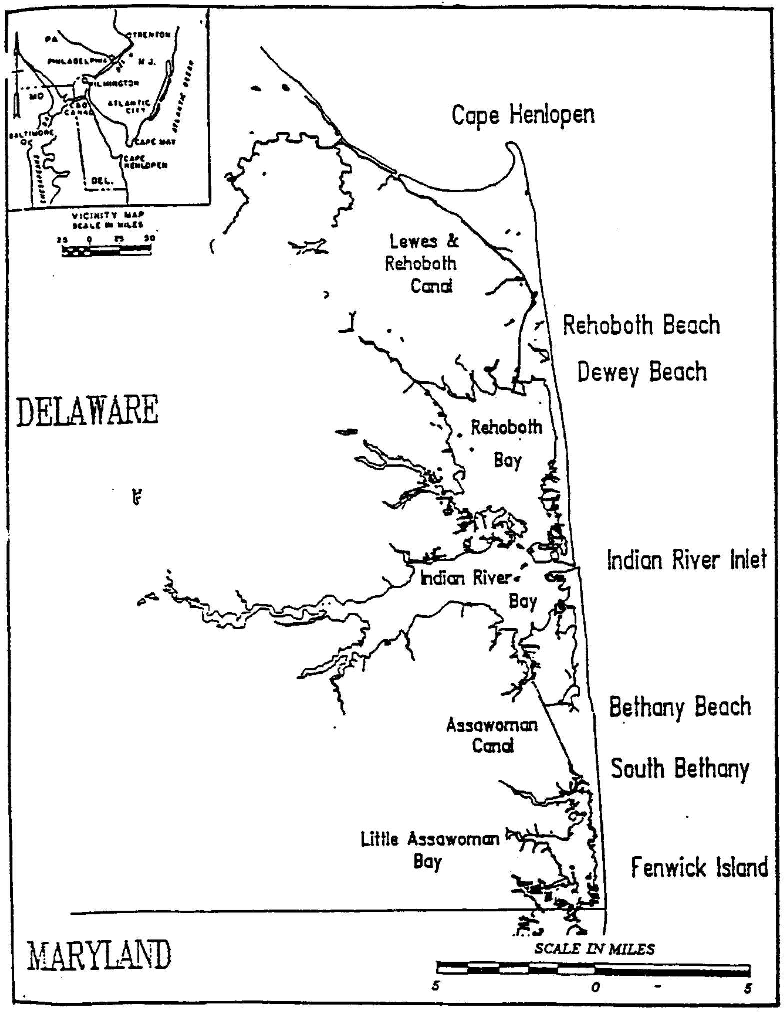
10. The Atlantic Coast of Delaware, located entirely in Sussex County, stretches from Cape Henlopen in the north to the southern border of Delaware with Maryland as shown in Figure 1. The Delaware Atlantic Coast is approximately 24 miles long and consists of six incorporated communities: Henlopen Acres, Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany and Fenwick Island. Several unincorporated private developments also exist in the study area.

11. Three state parks are located along the coast. Cape Henlopen State Park is located in the northern part of the coast from Cape Henlopen to the private community of North Shores. Delaware Seashore State Park exists both north and south of Indian River Inlet in the central part of the coast. Fenwick Island State Park is located in the southern part of the coast between South Bethany and Fenwick Island.

12. Three shallow water bays border the study area to the west. They are Rehoboth Bay, Indian River Bay and Little Assawoman Bay.

13. From north to south the study area includes the incorporated town of Rehoboth Beach, the unincorporated region in front of Silver Lake (under Sussex County jurisdiction) and the incorporated town of Dewey Beach. A project area map is shown in Figure 2.

14. **Rehoboth Beach.** The incorporated town of Rehoboth Beach, is a headland and lies directly south of the State-owned area known as Deauville and extends south for approximately 1 mile. The elevation of the beach is generally +7 ft NGVD while the elevation of the upland area (developed area landward of the beach) is generally ranges from +22 ft NGVD, except in the areas around Lake Gerar, in the north part of town to +16 ft NGVD on the southern edge of the town at Silver Lake. Along the beach are 9 locally constructed groins. All of the groins are in poor condition, however, they are functioning and are in no imminent danger of failing. The three northernmost groins continue to function, however, they are exposed to the predominant wave action from the northeast and have been damaged in recent storm events.


PA
TRENTON
PHILADELPHIA
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WILMINGTON
MD
ATLANTIC CITY
BALTIMORE
CAPE MAY
CAPE HENLOPEN
DEL.
VICINITY MAP
SCALE IN MILES
Cape Henlopen
Lewes &
Rehoboth
Canal
Rehoboth Beach
Dewey Beach
DELAWARE
Rehoboth
Bay
Indian River Inlet
Indian River
Bay
Bethany Beach
Assawoman
Canal
South Bethany
Little Assawoman
Bay
Fenwick Island
MARYLAND
SCALE IN MILES
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Figure 1

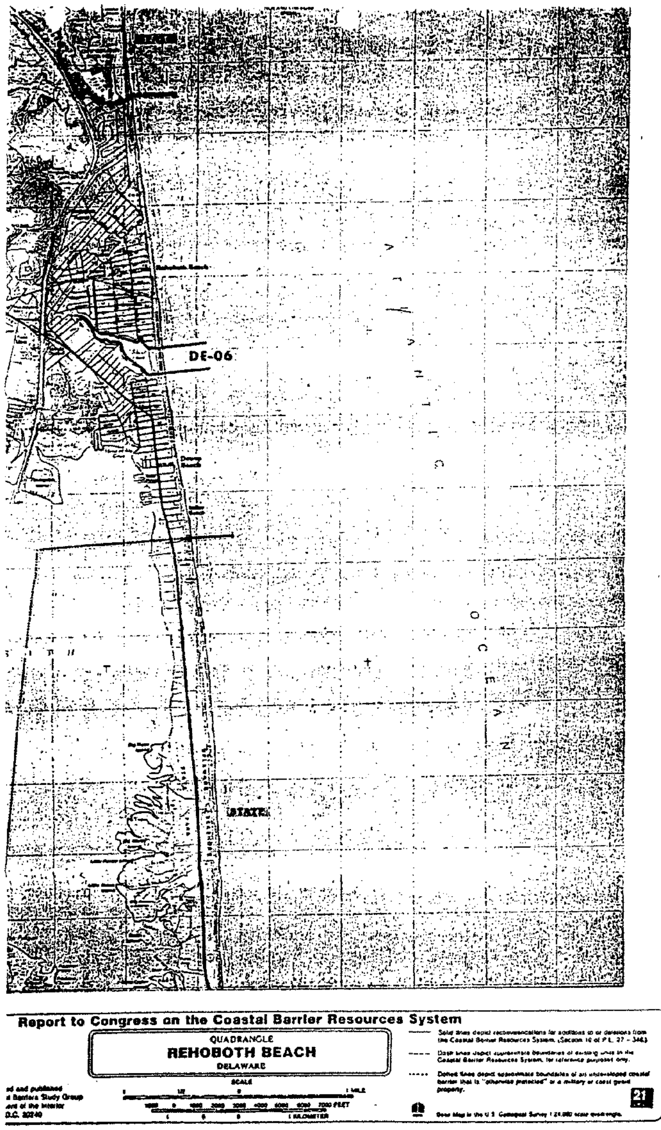
DE-06
STATE
Report to Congress on the Coastal Barrier Resources System
QUADRANGLE
REHOBOTH BEACH
DELAWARE
SCALE
1 MILE
7000 FEET
1 KILOMETER
Solid lines depict recommendations for additions to or deletions from the Coastal Barrier Resources System. (Section 10 of P.L. 97 - 348.)
Dash lines depict approximate boundaries of existing units in the Coastal Barrier Resources System, for reference purposes only.
Dotted lines depict approximate boundaries of an undeveloped coastal barrier that is "otherwise protected" or a military or coast guard property.
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Figure 2

15. The town of Rehoboth Beach is highly developed with generally suburban characteristics. The main commercial district lies along Rehoboth Avenue which runs from Route 1 in the west to the Atlantic Ocean in the east. Areas north and south of Rehoboth Avenue are generally residential in nature. Along the beach is a recreational boardwalk extending from just south of Lake Avenue in the north 5250 feet south to Prospect street. Commercial businesses are established along the northernmost 3500 feet of the boardwalk with the remaining part of the boardwalk fronted by residential structures.

16. **Silver Lake Region.** The Silver Lake region consists of the 1000 feet (north to south) area between Rehoboth Beach to the north, Dewey Beach to the south, the Atlantic Ocean to the east and Silver Lake in the west. The width of this area (east to west) varies from 800 feet in the north to 500 feet in the south. The elevation of the beach is generally +7 ft NGVD. There are no groins present along this stretch of beach. The Silver Lake region is currently under the jurisdiction of Sussex County and has been designated a Coastal Barrier Resources Unit by the Department of the Interior. Development of the Silver Lake area began prior to the initiation of this feasibility study and will continue into the future regardless of the presence of a Corps project. Two development companies purchased the land at Sliver Lake and partitioned it into 15 lots. Utilities, including sewer and electric lines have been installed for all 15 lots and currently there are 15 private residences planned for construction. Active marketing to sell these lots and construct houses on them has been ongoing for the past few years. Many of the lots have already been sold and houses have been built on some of them. It is expected that all of these structures will be completed by the base year for this study. However, none of the structures were included in the damage analysis.

17. **Dewey Beach.** The incorporated town of Dewey Beach lies directly south of the Silver Lake region and extends south for approximately 1 mile. Immediately to the south of Dewey Beach is the unincorporated town of North Indian Beach. Dewey Beach is headland in the north with the southernmost 3000 feet composed of barrier island with the Atlantic Ocean to the east and Rehoboth Bay to the west. The width of the barrier island on which the southern half of the town of Dewey Beach lies is generally 1500 feet. The elevation of the beach is generally +7 ft NGVD while the elevation of the upland area is generally +16 ft NGVD in the northern part of the town decreasing to +10 ft NGVD in the southern part of the town.

18. The town of Dewey Beach is highly developed with generally suburban characteristics. Route 1, which runs through the middle of town (north to south), is where most of the commercial businesses are located. The remainder of the town is a mix of residential and commercial interests.

PRIOR STUDIES, REPORTS AND RELATED PROJECTS

19. There exists numerous planned and completed shoreline protection programs and projects for the Atlantic Ocean coast of Delaware. The work has been initiated by Federal Government and the State of Delaware. The description of each of these projects are included in Table 1.

TABLE 1
PRIOR STUDIES AND REPORTS

REPORT TITLE	DATE	REMARKS
Delaware Coast from Kitts Hummock to Fenwick Island H.D. 85-216	30 July 1957	Authorized Act of 3 July 1958 which entitled Federal participation in cost of restoration and subsequent periodic nourishment, not to exceed 10 years, of the shore from Rehoboth Beach to Indian River Inlet, DE. No action was taken.
Hurricane Study--Atlantic Coast of Southern New Jersey and Delaware H.D. 89-238	December 1964	Chief of Engineers recommended that improvements for hurricane protection not be undertaken.
Delaware Coast Feasibility Report	1966	Recommended plans of improvement along entire ocean coastline of Delaware. Plans of improvement included beach nourishment, construction of dunes and bulkheads and rehab and replacement of existing structures.
Delaware Coast, Beach Erosion Control and Hurricane Protection S.D. 90-90	2 July 1968	Review of H.D. 85-216. Recommends a project authorizing Federal participation in two reaches: Cape Henlopen to Indian River Inlet and Indian River Inlet to Fenwick Island. Led to 1972 GDM.
Delaware Coast, Beach Erosion Control and Hurricane Protection, GDM Phase I	December 1972	Generally, provided widening of the construction of a continuous dune to elevation +17.0 mlw except at developed areas where bulkheads would be built. Reaffirms project plan of S.D. 90.
Delaware Coast, Beach Erosion Control and Hurricane Protection, GDM Phase II	May 1975	Plan included beachfill with periodic nourishment for Reach 1 (Cape Henlopen to Indian River Inlet) and Reach 2 (Indian River Inlet to the DE-MD state line. Plan also included upgrading groins at Rehoboth Beach and rebuilding/upgrading groins at Bethany Beach. No action resulted.
Final Environmental Impact Statement--Draft Supplement for the Beach Erosion Control and Hurricane Protection Program for the Atlantic Coast of Delaware	1975	Draft Supplement EIS for the GDM Phase I of December 1972.
Delaware Coast Beach Erosion Control and Hurricane Protection, GDM Phase II, Supplement No. 1.	February 1976	Responses to comments and/or questions pertaining to hydraulic design factors and criteria contained in the Delaware Coast Beach Erosion Control and Hurricane Protection GDM Phase II.
General Design Memorandum and Environmental Assessment, Atlantic Coast of Delaware (includes Atlantic Coast of Delaware Reevaluation Report)	November 1984	Examined three areas: north of Indian River Inlet, Bethany Beach to South Bethany and interior shorelines of Indian River Inlet. Project recommended and resulted in construction of sand-bypass plant at Indian River Inlet and stone revetments on the north and south interior shore of the inlet.
Erosion Control Study--Detailed Project Report and Environmental Assessment	May 1985	Two reports that deal with the respective erosion problems of north and south interior shorelines of Indian River Inlet.

20. **Federal.** The history of Corps involvement along the Atlantic Ocean coast of Delaware is long and involved. Before 1930, Federal government involvement in shore protection was limited to protection of public property. With the enactment of The River and Harbor Act of 1930 (Public

Law 71-520, Section 2) the Chief of Engineers was authorized to conduct studies of erosion problems in cooperation with municipal and state governments in order to devise a means of preventing further erosion of the Nation's shores. Until 1946, Federal aid was limited to studies and technical advise. In that year, and again in 1956 (PL 84-826) and 1962 (PL 87-874), the law was amended to allow Federal participation in the cost of shore protection projects and enabled limited contribution to the protection of private property, provided such protection would benefit the general public.

21. In a report dated 24 August 1936 the Shore Protection Board (now the Coastal Engineering Research Board) determined that the jetties prepared for the Indian River Inlet would have little or no effect on the local beach erosion problem.

22. H. Com. 41, 75th Congress, 1st Session, authorized the Act of 26 August 1937. The Act authorized a 15-foot deep inlet channel to Indian River Bay, two jetties and a 15-foot deep channel in the bay to a point 7,000 feet from the ocean shoreline, thence decreasing to a 6-foot depth.

23. The beach erosion control study covering the area from Kitts Hummock to Fenwick Island, was conducted on a cooperative basis with the State of Delaware. The resulting report was submitted to Congress by the Secretary of the Army on 14 June 1957, and printed in House Document No. 216, 85th Congress, 1st Session. That report presented plans of shore protection for Kitts Hummock, Slaughter Beach, Broadkill Beach and Lewes Beach along the Delaware Bay shore of Delaware; and Bethany Beach and the reach from Rehoboth Beach to Indian River Inlet along the Atlantic Ocean coast of Delaware. The plans of protection which were found suitable consisted of the artificial placement of material to widen the beaches, and the construction or repair of groins at various locations as required to assist in retaining the fill. The report concluded that improvements at all areas except the area from Rehoboth Beach to Indian River Inlet were not economically justified since the cost of providing protection would be in excess of the benefits that were reasonably assured from the proposed improvements.

24. The project, Rehoboth Beach to Indian River Inlet, was adopted by Congress in the River and Harbor Act of 1958. The Act authorized Federal participation in cost of restoration and subsequent periodic nourishment, not to exceed 10 years, of the shore from Rehoboth Beach to Indian River Inlet, Delaware. The accretion can be partially attributed to the 1,040,000 cubic yards of sand placed on the beach in 1957, 1961 and 1963 under the authorization cited above, and to the emergency dune and beach fill placed after the storm of March 1962. The material placed on the beaches during the period between 1957 and 1961 was substantially lost during the coastal storm of March 1962. Emergency work to restore the beaches and the construction of the dune was undertaken by the Federal Government and was completed by September 1962.

25. A report entitled "After Action Report on Operation Five-High", dated August 1963 was prepared by the North Atlantic Division, Corps of Engineers. The report presents details concerning the extent and characteristics of the devastating coastal storm of 6-8 March 1962; the damages incurred; and emergency restoration work accomplished under provisions of Public Law 875, 81st Congress, by the North Atlantic Division in its area of responsibility along the coasts of New York,

New Jersey, Delaware, Maryland and Virginia.

26. A report on the hurricane damage prevention study of the Atlantic Ocean coast of Southern New Jersey and Delaware was submitted to Congress in December 1964 and printed in House Document No. 38, 89th Congress, 1st Session. The Chief of Engineers recommended in the report that improvements for prevention of hurricane tidal flooding along the Atlantic Ocean coast of Southern New Jersey and Delaware not be undertaken by the United States at that time. The study considered plans to provide complete protection along problem areas, and limited protection along other areas of the ocean front. It was determined that complete protection could be provided for each problem area by a massive barrier-type structure, such as seawalls or dikes, which would not be feasible for both economic and aesthetic reasons. It was also determined that partial protection could be provided by a stone revetment along the ocean front, but this lower degree of protection could not be economically justified at any of the problem areas.

27. The Delaware Coast Feasibility Report of 1966, authorized under Section 103 of the River and Harbor Act of 1962 and described in House Document No. 216, 85th Congress, 1st Session, focused on developing solutions for storm damage reduction for the Delaware Bay coast as well as the Atlantic Ocean coast of Delaware. The plans of improvement provide beach erosion control and hurricane protection for the entire Atlantic coast of Delaware from Cape Henlopen to Fenwick Island. The plans consisted generally of the construction of dunes and the placement of beachfill, the construction of bulkheads at Rehoboth Beach, Dewey Beach and Bethany Beach, periodic nourishment of beaches, placement of sand fences, planting of dune grass and the maintenance and replacement of existing shore protection structures. These plans were never implemented with the exception of advance construction of the feeder beach north of Indian River Inlet.

28. The Beach Erosion Control and Hurricane Protection Plan of Study--Advanced Engineering and Design dated 23 May 1983 provided the plan of study for the "Atlantic Coast of Delaware Reevaluation Report" (included as Appendix to GDM of 1984). This reevaluation report developed a scaled down version of the shore protection plan outlined in the Delaware Coast authorization of 1968. The reevaluation report and subsequent 1984 GDM focused on the areas: a) north of Indian River Inlet; b) Bethany Beach and; c) the north and south interior shorelines of Indian River Inlet. The erosion of the interior shorelines of Indian River Inlet were recommended to be pursued under the Continuing Authorities Program of Section 103 of the River and Harbor Act of 1962, as amended. Stone revetments were completed in September 1989 to stabilize these shorelines.

29. The Delaware Coast GDM of 1984 addressed the erosion problems occurring at the shore immediately north of Indian River Inlet where Route 1 was being threatened. The recommended plan consisted of beach nourishment utilizing a fixed sand bypass plant at Indian River Inlet. The bypass plant, which was completed and went into full operation in 1990, is located on the south side of the inlet and consists of a semi-mobile jet pump system with an operations building containing the pumps. Sand is removed from the south jetty fillet area and pumped via pipeline over the Route 1 bridge to be discharged at various points along a 1500 ft section of the shore north of the inlet. The plant was designed to pump on the average 100,000 cubic yards of sand per year.

30. **State.** A number of shore protection measures along the Atlantic Ocean coast of Delaware have been taken by the State.

31. A report dated 18 January 1921 sponsored by the State of Delaware recommended construction of jetties and groins at Rehoboth Beach.

32. A total of 25 groins were constructed in the area between Rehoboth Beach and Bethany Beach by the State during the period between 1962 and 1964.

33. In 1963 the State of Delaware placed 590,000 cubic yards of beach fill along the beach north of Indian River Inlet in accordance with the 3 July 1958 authorized project. The State awarded a contract in early November 1972 for the placement of approximately 600,000 cubic yards of sand along the beach north of Indian River Inlet with the sand being obtained from the Inlet. The project was accomplished in accordance with the plans under the authorization of Senate Document No. 90, and was eligible for Federal participation in the amount of 70% of the cost. The project when completed restored the beach and reinforced the dune along a one mile stretch starting immediately north of the Indian River Inlet north jetty.

34. In the mid to late 1980s, Delaware's southern beaches (Bethany Beach, South Bethany and Fenwick Island) experienced a loss of shoreline protection due to chronic erosion problems. Considering the proximity of the nourishment project at Ocean City, MD and its associated equipment, the DNREC contracted to have beachfill placed at all three towns utilizing this equipment. Subsequently, Fenwick Island was nourished in 1988 and 1992 and South Bethany and Bethany Beach were nourished in 1989 and 1992.

35. In the summer of 1994 the DNREC, again taking advantage of the equipment in place for the Ocean City, MD Federal beachfill project, placed approximately 600,000 cubic yards of beachfill material at Dewey Beach. In addition, maintenance fill was placed along the shorelines of Bethany Beach and South Bethany.

36. In addition to the reports presented above, studies and reports have been prepared by the Shore Protection Board, the State of Delaware and the Corps of Engineers pertaining to the problems of flood control, coastal erosion and shore protection. Several brief reconnaissance studies resulting from reports or complaints of beach erosion conditions at specific localities in the study area have also been made by the Corps of Engineers.

RELATED INSTITUTIONAL PROGRAMS

37. **Coastal Barrier Resources Act.** The Coastal Barrier Resources Act (CBRA) was enacted on 18 October 1982 (Public Law 97-348) and amended 16 November 1990. Its purposes are to protect undeveloped barrier islands and to restrict future Federal expenditures and financial assistance

which encourage development of coastal barriers. Through CBRA, the Secretary of Interior is empowered to implement a Coastal Barrier Resources System (CBRS) consisting of undeveloped coastal barriers on the Atlantic and Gulf Coasts.

38. Limitations on Federal spending are enumerated in Section 5 of the CBRA. These limitations prohibit expenditures for:

a. Construction or purchase of any structure, appurtenance, facility, or related infrastructure.

b. Construction of roads, airports, boat landing facilities or bridges or causeways to any System Unit.

c. Carrying out of any shoreline stabilization (erosion) projects except where an emergency threatens life, land, and property immediately adjacent to the unit.

39. The Act also stipulated that the Secretary of Interior should submit a report to Congress by 18 October 1985 containing: (a) recommendations for conservation of the fish, wildlife, and other natural resources of the system and (b) recommendations for additions to, or deletions from, the Coastal Barrier Resources System and for modifications to the boundaries of the System Units. Two major changes to the CBRS which have been proposed by United States Fish and Wildlife Service (USFWS) are: (1) to include public lands (protected lands) such as state parks, Federal parks, wildlife refuges and National Seashores and (2) to include secondary barriers.

40. Within this study area, there is one CBRS Unit. It is a 0.3 mile section of shoreline adjacent to Silver Lake between Rehoboth Beach and Dewey Beach as shown in Figure 2. This section was added to the CBRS during the 1990 amendment. It is composed of a wide beach with dunes and scattered vegetation. This area has occasionally been overwashed during storms but is not currently in danger of being breached.

41. **National Estuary Program--Inland Bays Estuary Program.** The National Estuary Program (NEP) was established by Congress under the Water Quality Act of 1987, section 317. The purposes of the NEP are: (1) to identify nationally significant estuaries threatened by pollution, development, or overuse; (2) promote comprehensive planning, conservation and management of nationally significant estuaries; and (3) encourage the preparation of management plans and enhance coordination of estuarine research. These goals are to be achieved for estuaries in the NEP by a Comprehensive Conservation and Management Plan (CCMP), developed in a management and study effort called a Management Conference.

42. The Inland Bays Estuary Program in the State of Delaware was designated into the National Estuary Program in 1988. The Environmental Protection Agency designated Delaware's Inland Bays on the basis of their national significance, and the need for their protection. The seven purposes of the Inland Bays Estuary Program includes: (1) to assess trends in water quality, natural resources,

and estuary uses in order to identify problems; (2) to collect, characterize, and assess data on toxins, nutrients, and natural resources to identify causes of estuarine problems; (3) to develop relationships between pollutant loadings and water quality, natural resources and potential uses to identify problem remedies; (4) to develop a comprehensive conservation and management plan specifying corrective actions and timetables; (5) to develop plans for coordinated implementation; (6) to monitor the effectiveness of actions taken; and (7) to review all Federal financial assistance programs and development projects for consistency with the management plan.

43. The Inland Bays Estuary Program study area includes (1) Delaware's Rehoboth, Indian River and Little Assawoman Bays; (2) all tidal tributaries to these waters; and (3) the surrounding land areas.

PROBLEM IDENTIFICATION

44. Water resource problems associated with the main study objectives are identified below. The problems which exist in the study area were identified during site visits, literature review, public and interagency coordination, surveys and aerial reconnaissance flights.

45. **Problem Analysis.** The principal water resources problem categories identified in Rehoboth Beach and Dewey Beach are 1) storm damage vulnerability with a high potential for storm-induced erosion, inundation and wave attack which is exacerbated by 2) long term shoreline erosion.

46. The ground elevation of Rehoboth Beach and Dewey Beach decreases from +22' NGVD in the northern part of Rehoboth Beach to +10' NGVD in the southern part of Dewey Beach. Although some areas have dunes, the ocean shoreline along the study area consists predominantly of a continuous strip of low lying beach with a series of 9 groins along the oceanfront in Rehoboth Beach.

47. **Storm Damages.** The principal source of economic damages identified in Rehoboth Beach and Dewey Beach are storms. Severe storms in recent years have caused a reduction in the overall dune height and berm height and width along the study area, as well as deterioration of the three northernmost locally constructed groins. These existing conditions expose the towns of Rehoboth Beach and Dewey Beach to potentially catastrophic damage from ocean flooding and wave attack.

48. ***Storm History.*** In recent years erosion problems have become more critical as several coastal storms have buffeted the Atlantic coast of Delaware. Since the March 1962 storm (Figure 3) which caused, in 1962 dollars, $16.7 million in damages, the most notable storms have occurred in December 1974, October 1977, March 1984, September 1984, October 1991, January 1992 and December 1992. It should be noted that the January 1992 (Figures 4 and 5) and December 1992 storms (Figure 6) resulted in the President of the United States declaring Sussex County, DE, which includes the entire Atlantic Ocean coast of Delaware, a National Disaster Area.

49. **Long Term Shoreline Erosion.** Progressive and constant erosion is evident along the

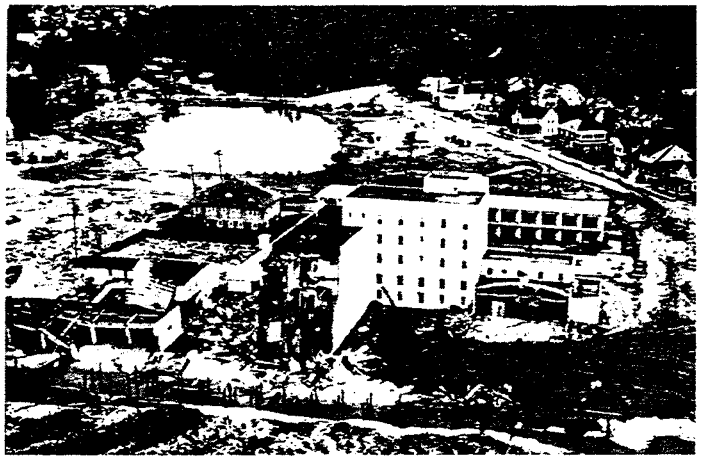


Figure 3. Rehoboth Beach, Henlopen Hotel, March 1962

Figure 4. Dewey Beach, January 1992

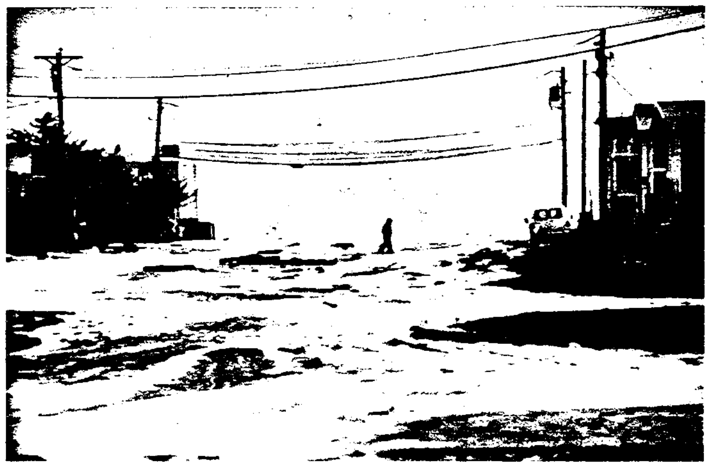


Figure 5. Dewey Beach, January 1992

Figure 6. Dewey Beach, December 1992

coastline of the study area. Historically, beach erosion has been recorded in Delaware since 1843, though according to Goodman (1973), it was not a significant problem until the 1950's when tourism, and hence development, increased, and the economic impact of beach erosion became apparent. Local interests constructed groins in Rehoboth Beach between 1922 and 1964 indicating that beach erosion was in fact a problem prior to 1950. Efforts undertaken to minimize losses associated with storm damage include building code improvements and building restrictions. However, many portions of the developed coast still remain vulnerable due to the proximity of structures to the beach and the level of development.

50. It should be noted that simply because an area may exhibit relative stability or a low background erosion rate does not preclude the need to fully address options for additional shore protection. As mentioned earlier, in the case of Rehoboth Beach, which lost a great deal of beach elevation during the recent storms, much of the existing beachfront lacks an adequate dune system.

51. **Sponsor Concerns.** The non-federal sponsor for this feasibility study is the Delaware Department of Natural Resources and Environmental Control (DNREC). Currently, DNREC's concern, within the scope of this interim feasibility study, is to enter into a long term partnership with the Federal Government to provide hurricane and storm damage protection for the towns of Rehoboth Beach and Dewey Beach in a manner that maximizes the use of limited state resources and funds.

EXISTING CONDITIONS

PHYSICAL SETTING

52. **Tides.** Tides along the Delaware coast are of the semi-diurnal type, with two nearly equal high tides and two nearly equal low tides. The ocean tidal ranges are published by the National Oceanic and Atmospheric Administration (NOAA). Mean and Spring tide ranges are listed in Table 2.

TABLE 2
OCEAN TIDE RANGE (FEET)

LOCATION	MEAN	SPRING
Cape Henlopen	4.1	4.9
Rehoboth Beach	3.9	4.7
Fenwick Island Light	3.7	4.5
Ocean City, Maryland	3.5	4.2

53. **Wind.** Data on wind over the ocean are available from charts compiled and published by the U.S. Navy Hydrographic Office as well as the Coastal Engineering Research Center's Wave Information Study, (WIS), for the period 1956 through 1988. The available data show the prevailing wind direction at the Delaware coast to be blowing offshore out of the southwestern and northwestern quadrants. However, winds from other directions are nearly as frequent. The winds blowing from the northeastern and southeastern quadrants have the largest influence on the direction of littoral transport and storm attack along the Atlantic Ocean shoreline of Delaware. In the 5° quadrangle nearest the Delaware coast the winds are distributed with respect to direction as follows: onshore (northeast, east and southeast) 27 percent; alongshore (south and north) 11 and 15 percent respectively; offshore (southwest, west and northwest) 44 percent.

54. **Waves.** Wave data for the study area was developed from the 20 year hindcast of general wave climatology presented in the recent Corps of Engineers, WIS Report 30 prepared by the Coastal Engineering Research Center, (CERC, Hubertz, et al.. 1993). As part of the present study's wave climate analyses, CERC hindcasted two supplementary years of wave data at the Delaware Coast WIS stations, January 1990 to January 1992, inclusive. The wave statistics found in the WIS pertinent to the Delaware coast are for Stations 65, and 66 both at a water depth of 18 meters (59.1 feet). Waves approach the coast from the northeast and southeast quadrants, with the highest occurrence levels from the east and southeast directions. The highest significant wave height reported

from the hindcasts at Stations 65 and 66 was 7.7 meters (25 feet) recorded during the March 1962 Northeaster.

55. In addition, as part of the current feasibility study, a directional wave gage was placed offshore of Dewey Beach in a water depth of 30 feet. The gage recorded data from October 1992 through December 1993. During the 15 month deployment, the observed data shows the same trend as WIS hindcast. The predominant wave direction is from the east and southeast, with the highest waves being recorded from the east-northeast during storms. The highest wave height, 4.1 meters (13.5 feet), was recorded during the December 1992 northeaster.

56. A wave height frequency relationship was developed from the WIS hindcast information to obtain representative storm wave conditions at the 18 meter, (59.1 feet), depth offshore of the study area. The analysis determined the 100 year frequency wave height to be 6.8 meters, (22.6 feet). The results of the storm wave conditions analysis, including the corresponding wave periods are summarized in Appendix A, Section 2.

57. **Sea Level Rise.** Sea level rise is generally considered to be a contributing factor to long-term coastal erosion and increases the potential for coastal inundation. Because of the large variability and uncertainty of the climatic factors that affect sea level rise, predicting future trends with any certainty is difficult. Based on Corps of Engineers guidance EC-1105-2-186, until substantial evidence indicates otherwise, local regional history of sea level changes will be used to forecast a change in sea level for a specific project area. Based on historical gage records at Breakwater Harbor, DE, sea level has been rising 0.0102 feet per year (Hicks and Hickman, 1986). The ocean-stage frequency analysis, historic shoreline analysis, and required nourishment rate estimates incorporate the effects of sea level rise.

58. **Storms.** There are two major types of damaging storms which affect the Delaware coast. They are "tropical", hurricanes and tropical storms, and "northeasters", or "extra-tropical" storms. Hurricanes usually diminish in intensity by the time they reach the Delaware coast during their usual northward movement. No hurricane storm center has made landfall along the Delaware coast since records have been kept (1871). However, several tropical storms and hurricanes have passed near the Delaware coastline in this period. A number of these have caused significant damage, including the great Atlantic hurricane of 1944. Northeasterly storms occur more frequently than hurricanes and usually are associated with longer durations of storm surge and high waves which cause considerable beach erosion and flooding along the coast of Delaware.

59. The most damaging storm to affect the study area during this century was the northeaster of March 6-8, 1962. The combined storm tide elevation of +8.1' NGVD, (adjusted for sea level rise), was the highest recorded in the period of record at Breakwater Harbor, Delaware. In recent years the area has experienced a high number of large Northeasters, which have produced stages among the highest in the period of record: October 1991 (the "Halloween" storm), January 1992, December 1992, March 1993, & March 1994. The January 1992 storm produced the second highest stage recorded at the Lewes gage, +7.3' NGVD. Also see the section on problem identification.

60. **Ocean Stage-Frequency.** A stage frequency analysis was performed to assess the potential for erosion and inundation along the ocean coastline of Delaware. Because of the infrequent occurrence of hurricanes at a given site, it was felt that a statistical approach to extreme events coupled with the existing record of stages at the Breakwater Harbor gage would lead to a better representation of possible low frequency stage events. Hurricanes and northeasters were treated separately to yield individual exceedence frequency curves, which were then combined in accordance with EM-1110-2-1412 to attain a single curve for use in design. The results of the ocean stage frequency analysis are presented in Appendix A, Section 2. Table 3 presents the adopted stage frequency data at the Rehoboth Beach/Dewey Beach study area for selected recurrence intervals.

TABLE 3
REHOBOTH BEACH AND DEWEY BEACH
OCEAN STAGE FREQUENCY DATA

ANNUAL PROBABILITY OF EXCEEDENCE	ELEVATION FEET NGVD
0.990	5.6
0.500	6.4
0.100	7.1
0.050	7.9
0.020	9.0
0.010	9.8
0.005	10.6
0.002	11.5

61. **Inland Bays Stage-Frequency.** During coastal storms the open coast, as well as the inland bays of the study area will become flooded above normal tidal levels due to increased flow through Indian River Inlet. Frequencies of still water elevations were developed for the inland bays in the 1992 FEMA "Flood Insurance Study for Sussex County Delaware", and are presented in Table 4. It is assumed that since there will be no surge barriers introduced in the inland bay, since this study only includes the ocean front, there will be no anticipated difference in inland bay induced flooding between the without and with-project conditions.

TABLE 4 STILL WATER ELEVATIONS vs. RECURRENCE INTERVAL FOR INLAND BAYS (FEET NGVD)		
	LOCATION	
RECURRENCE INTERVAL	REHOBOTH BAY	INDIAN RIVER BAY
5	3.2	4.2
10	3.9	4.7
50	5.9	6.4
100	7.0	7.5
500	10.8	10.8

62. **Geology.** Delaware encompasses segments of two regional physiographic-geologic provinces. The extreme northern portion of the state lies within the Appalachian Piedmont province, an area characterized by an exposed bedrock complex consisting of metamorphic and igneous rocks. The eroded surface of this complex slopes south and east to the sea, forming the depositional basement for the wedge-shaped mass of essentially unconsolidated sediments commonly referred to as the Atlantic Coastal Plain Province. This wedge, believed to reach a thickness of approximately 7,800 feet at Fenwick Island, extends eastward beyond the edge of the continental shelf which is considered a part of the Coastal Plain. As a result, this province can be divided into two sections: a submerged portion, commonly referred to as the continental shelf and a subaerial or emerged portion, with the present Atlantic coast shoreline forming the boundary between the two. The area under investigation lies totally within the Atlantic Coastal Plain approximately 85 miles southeast of the Fall Line (the exposed edge of the Piedmont) and encompasses segments from both the submerged and emerged portions of the province. The boundary between the two portions is characterized by an ever-changing complex of depositional environments associated with the Atlantic barrier system. These environments, which include coastal marshes, tidal lagoons and beach-dune complexes, represent the leading edge of an on-going marine transgression, which over the past 15,000 years has caused the shoreline complex to advance across approximately two-thirds of the Coastal Plain province to its present position. This transgression is occurring in response to a relative rising of the sea level. The current rate of rise is estimated to be approximately 1.0 foot per century along the Delaware Atlantic Ocean coast.

63. The shoreline of the Atlantic Ocean coast of Delaware consists of a continuous, wide, sandy baymouth barrier except for a break at Indian River Inlet. Coastal barrier beaches may be considered a continually moving geomorphic form with materials eroding from the beach face and accreting

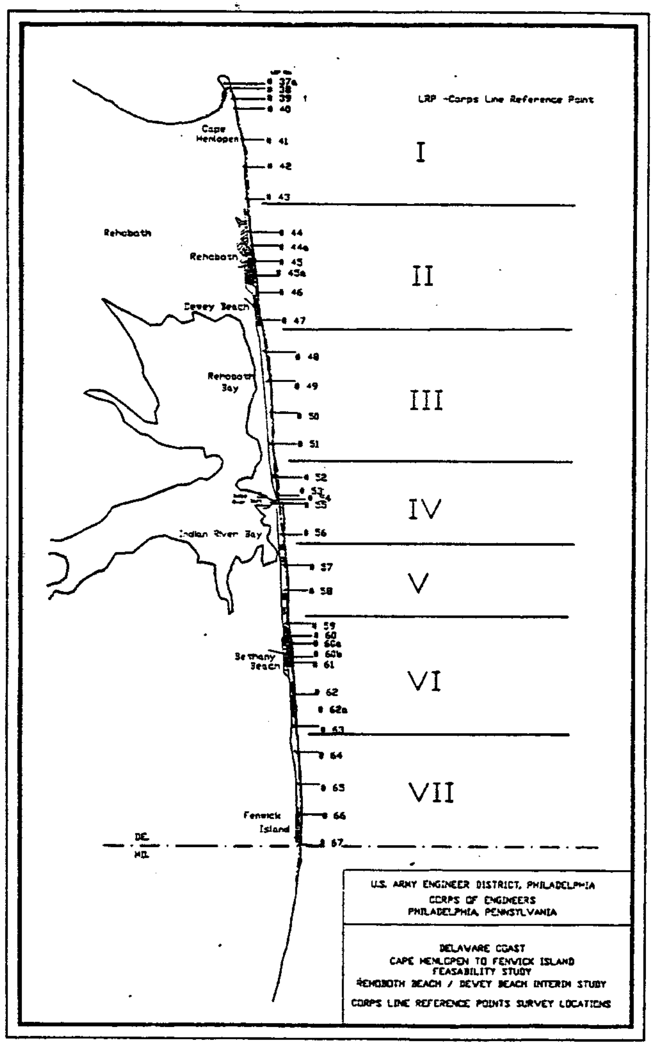
landward and upwards across the coastal lagoonal areas.

64. *Surficial Deposits.* The coastal area can be divided into two zones of similar geology; the Cape Henlopen Spit complex, and the baymouth barrier, lagoon, and highland complex between Rehoboth Beach and Fenwick Island. The Cape Henlopen complex is comprised of a washover barrier tract north of Rehoboth Beach extending to Cape Henlopen, a beach face/berm and dune system, and a large tidal flat. The stratigraphy of sediments in the spit dune area indicate beach and spit sands and gravels interbedded with shallow marine-estuarine silts (Kraft, University of Delaware).

65. The second area, the baymouth barrier, lagoon and highland complex is characterized by rapid erosion, predominantly coastal washover erosion. The barrier erodes at the beach face and nearshore area and accretes in a landward direction. The beach face is rather steep and the berm is comprised of horizontally laminated coarse to medium sand. A generalized vertical sequence of sediments found at Dewey Beach and south indicate dune washover sands overlying back barrier marsh sediments (clayey sand and peat) which contain tree stumps from an ancient pine forest. Below this are tidal delta sands and gravels followed by lagoonal sand and silt, and in some cases a small underlying pocket of beach sand. Marsh muds and peats are then encountered followed by a marsh fringe of muddy sand and grass roots and/or tree stumps. Pleistocene coastal sediments then form the base. When large storms occur, the beach berm sand may be washed over the barrier into coastal lagoons, sometimes exposing the marsh peats and tree stumps normally buried five to seven feet below the beach berm system. This extensive forest has been exposed along the length of the Delaware ocean coast, except at the Pleistocene highlands at Bethany Beach and Rehoboth Beach. As a result of the beach erosion, rounded masses of peat and marsh mud called "marshrollers" are often found moving along the surf adjacent to the eroding shoreline.

66. **Existing Beaches.** The Delaware Ocean coastline from the tip of Cape Henlopen to the southern border of Delaware with Maryland, is approximately 126,500 feet (24 miles) in length. This shoreline was subdivided into eight reaches based on their similarities in profile configuration, local coastal processes, upland development, and geographical proximity. The individual reaches are shown in Figure 7 and identified in Table 5.

67. Reach I is the Cape Henlopen spit system including Cape Henlopen State Park. Within reaches II & VI, the Rehoboth Beach & Bethany Beach areas are headland shorelines and are less susceptible to inundation than barrier beaches. The general existing conditions for both Rehoboth Beach and Bethany Beach consist of beaches with substantial widths, little or no dunes, typically having bulkheads backing the profiles and high backshore elevations. Both Rehoboth Beach and Bethany Beach have groin fields which have acted to stabilized the shoreline in recent history. However, both Reach II and Reach VI include areas outside of the groin field, Dewey Beach and South Bethany, respectively. Dewey Beach, is a transition area with two distinct topographic regions. The northern section of the community is a headland type beach and the southern section of the town can be classified as a barrier island beach typical of the Delaware ocean coast in reaches III, IV & V. South Bethany is characterized by its small beachface berm with little or no dunes and backshore areas of low elevations. Reaches III, IV, V, and VII, are barrier beaches separating the



LRP -Corps Line Reference Point
Cape Henlopen
Rehoboth
Rehoboth
Dewey Beach
Rehoboth Bay
Indian River Bay
Bethany Beach
Fenwick Island
DE.
MD.
I
II
III
IV
V
VI
VII
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
DELAWARE COAST
CAPE HENLOPEN TO FENWICK ISLAND
FEASABILITY STUDY
REHOBOTH BEACH / DEWEY BEACH INTERIM STUDY
CORPS LINE REFERENCE POINTS SURVEY LOCATIONS

Figure 7

TABLE 5 SHORELINE REACH IDENTIFICATION FOR THE ATLANTIC COAST OF DELAWARE		
REACH NUMBER	REACH LENGTH (Ft.)	LIMITS
I	26800	Cape Henlopen to N. Rehoboth Beach
II	13900	Rehoboth Beach & Dewey Beach
III	18300	South of Dewey to 2 miles north of Indian River Inlet.
IV	21100	Indian River Inlet area, 2 miles north and south.
V	11800	2 miles south of the inlet to North of Bethany Beach.
VI	15200	Bethany Beach & South Bethany
VII	19400	South Bethany to De/Md state line

ocean from back-bay areas, ranging from hundreds to several thousand feet wide. They are characterized as having relatively steep beaches with small to medium beachface-berm widths backed by dunes except in certain developed areas. The backshore areas are of low elevations which include bay marsh and mud flats. Though these reaches are in general similar, each has its own unique configuration of beach widths, dune heights and localized littoral processes.

68. **Sediment Transport.** The Atlantic Ocean coast of Delaware consists of approximately 24 miles of sandy shoreline which approximates a straight north-south line. Its continuity is interrupted only by Indian River Inlet midway along the study area. The coast is exposed to the essentially unlimited fetch of the open Atlantic Ocean from northeast through to the south, such that the physical processes of the shoreline are dominated by ocean waves. However, there are also regionally and locally important effects related to tidal circulation from the mouth of Delaware Bay and Indian River Inlet. The existence of tidal current effects has been recognized qualitatively for decades, but no investigation to date has attempted to resolve their relative magnitude of influence on longshore transport as compared to wave related effects.

69. At the northern end of the study area, the historic northward growth of the spit of Cape Henlopen is graphic evidence of the predominant northward longshore transport at that locality. At Indian River Inlet, 13 miles south of Cape Henlopen, the predominant transport direction is also northward, as evidenced by long-term accretion of the beach south of the south jetty and erosion

north of the north jetty. However, at Ocean City (Maryland) Inlet, located 9 miles south of Fenwick Island, predominant transport is clearly to the south as evidenced by accretion on the north (Ocean City) side of the inlet and significant erosion south of the inlet on Assateague Island. In the reach between Indian River Inlet and Ocean City Inlet there is a reversal in the direction of predominant longshore transport, which is referred to as a nodal zone.

70. The current analysis of sediment transport quantities determined potential net transport rates ranging between 150,000 to 250,000 cy/yr northward at Cape Henlopen, 75,000 to 150,000 cy/yr northward at Indian River Inlet and 125,000 to 200,000 cy/yr southward at the southern border of Delaware with Maryland. The gross transport quantities computed along the study area ranged from 700,000 cy/yr to 900,000 cy/yr. Additional information and sediment budget is presented in the section on shoreline change and Appendix A, Section 2.

71. **Historic Shorelines.** The historic shoreline analysis was conducted to document the past behavior of Delaware's Atlantic Ocean coastline, in order to make a reasonable estimate of "background" or long-term steady-state rates of shoreline change. Sediment transport patterns and shoreline change data were analyzed coast-wide to develop the estimates of historical shoreline behavior for each reach. The present analysis relied on a variety of information sources including aerial photography, beach profiles, Wave Information Studies, and pertinent reports of previous analyses.

72. A systematic analysis of beach profile data at established Corps of Engineers - Line Reference Points, (LRP), was carried out. The LRP Profiles represent a system of profile locations stretching from Cape Henlopen to the Delaware - Maryland border, Figure 7 presents the locations of the profile lines and there relationships to the various reaches. The LRP's were first surveyed in 1964 then not again until 1982, but have been consistently monitored between 1982 through 1993. The survey data from each LRP for all available years was plotted and shoreline position determined for each survey. A regression analysis was performed to determine the long term trend at each LRP location. In order to supplement the profile data analysis, two independent sets of Delaware shoreline change maps which include shorelines from the 1850's to 1988 were incorporated into the analysis. They were produced at the University of Maryland Laboratory for Coastal Research, using a Metric Mapping technique, (Galgano and Leatherman, 1988), and by the University of Virginia, (Dolan et al. 1978 & 1990), using a similar techniques. Recent aerial photography and photogrammetry, (1990 thru 1993) were employed to update the above analyses in order to estimate long-term change rates. Both sets of mapping yielded similar conclusions.

73. Table 6 presents a summary of the historic shoreline results. These were developed considering all of the available sources of historic shoreline information. A reasonable range and the average value of shoreline change rates are presented. The fluctuating rates within each reach indicate the variability spatially as well as temporally throughout the study area. It also serves to indicate the great potential for sediment movement along the entire Delaware shoreline. The average rate was adopted for use in estimating volumetric changes within each of the seven study reaches.

TABLE 6 HISTORICAL SHORELINE CHANGE		
REACH	CHANGE RANGE (FT/YR)	AVERAGE RATE (FT/YR)
I	+3 to -10	-5
II	+3 to -6	-3
III	0 to -8	-5
IV	No. -5 to -10 So. +4 to -3	No. -7 So. +2
V	+3 to -5	-3
VI	+3 to -2	-1
VII	+1 to -5	-2

NUMERICAL MODELING OF SHORELINE CHANGE

74. **General.** In recent years numerical shoreline change models have become an increasingly popular tool for investigating impacts of proposed coastal projects. Specifically, shoreline change models are ideally suited for tasks involving the analysis and evaluation of coastal projects with regard to the long-term fate of beachfills, renourishment cycles, and coastal structures designed to enhance the longevity of placed beach fill material. As part of this Feasibility study, a shoreline change model has been developed may be used for predicting relative future shoreline trends and responses along the Delaware coast between Cape Henlopen and Fenwick Island.

75. **Generalized Model for Simulating Shoreline Change (GENESIS).** The model being utilized for this study is GENESIS, developed by the US Army Corps of Engineers, Coastal Engineering Research Center, (Hanson and Kraus, 1989; Gravens, Kraus and Hanson; 1991). The acronym GENESIS stands for GENEralized Model for SImulating Shoreline Change and encompasses a group of programs developed for simulating wave-induced longshore sand transport and movement of the shoreline. GENESIS was developed to simulate long-term shoreline change on an open coast as produced by spatial and temporal changes in longshore transport (Hanson 1987, 1989; Hanson and Kraus 1989). Wave action is the mechanism producing longshore transport, and, in GENESIS, spatial and temporal differences in the transport rate may be caused by such diverse factors as irregular bottom bathymetry, wave diffraction behind structures, sources and sinks of sand, and constraints on the transport (resulting from structures such as seawalls and groins).

76. ***Capabilities and Limitations of GENESIS.*** GENESIS is designed to describe long-term trends of the beach plan shape change under imposed wave conditions, boundary conditions, and constraints imposed by coastal structures. GENESIS works best in calculating shoreline response

when the change will produce a long-term trend in shoreline movement, as it progresses from one equilibrium state toward another as a result of some significant perturbation. Shoreline change models are not applicable to simulating a randomly fluctuating beach system in which no shoreline movement trend is evident. GENESIS is not applicable to calculating shoreline change in the following situations which involve shoreline change unrelated to spatial differences in wave-induced longshore sand transport: beach change inside inlets or areas dominated by tidal currents (tidal currents have been qualitatively identified as a significant factor in sediment transport patterns along the Delaware); beach change produced by wind-generated currents; storm-induced beach erosion where cross-shore sediment processes dominate the beach evolution process (this type of beach evolution is best modeled using a cross-shore transport model such as SBEACH).

77. GENESIS is based on the one-contour-line beach evolution concept. It is assumed the beach profile maintains a constant equilibrium profile shape. This implies that the bottom contours are parallel and the entire profile is translated seaward or landward for an accreting or eroding shoreline, respectively. This assumption makes it necessary to consider the movement of only one contour line, for this study the Mean High Water (MHW) contour was utilized.

78. Beach profile data throughout the project area were analyzed to provide three parameters required for GENESIS: Average Profile Shape, Average Berm Elevation, D_B, and Depth of Closure, D_C. Being a "one-contour line" model, GENESIS does not model the offshore profile response, but assumes the beach profile moves landward and seaward while retaining the same shape. However, to determine the location of breaking waves alongshore and depth at the tips of structures that extend offshore, and to calculate the average nearshore bottom slope used in the longshore transport equation, a profile must be specified. An average profile shape was computed for the project area. An equivalent equilibrium profile was computed using Beach Morphology Analysis Package (BMAP) (Sommerfield et al. 1994). The "effective grain size" which corresponds to this profile is the required input for GENESIS.

79. ***Input Data Requirements.*** There are two dominant physical data types that must be assembled for input to GENESIS. These are shoreline position data and wave data. Wave data may be supplied in either of two ways depending on the degree of computational effort required. The first method consists of supplying an offshore time series of wave data and allowing the wave transformation model within GENESIS to calculate the breaking wave conditions along the modeled shoreline reach. An alternate method is to use a more sophisticated wave transformation model, such as the RCPWAVE model used within this study, to describe the wave propagation from offshore to shallow water across known bathymetry. For both types of wave input, longshore sand transport rates and the resulting change in shoreline position can be calculated as a function of the breaking wave field along the shoreline.

80. The shoreline position (defined by a single point along the beach profile) and a description of its movement over a specific time period is the focus of the GENESIS model. Consequently, the model requires specification of the initial shoreline at the beginning of all simulations. For comparison purposes, GENESIS also requires input of a measured shoreline position corresponding to the end

of a simulation, which is used to compute a calibration/verification error. Historic shoreline data ranging from 1964 through 1994 were digitally incorporated into GENESIS format for use in calibration, verification, and future conditions simulations. The shoreline positions were determined from both beach profile surveys (LRP Lines) and aerial photography.

81. In addition to these fundamental data types, GENESIS requires many other project specific, physical, and model setup inputs. Groins, bulkheads, and jetties exist throughout the project area, with each impacting the natural shoreline evolution differently. Specification of the structures by various parameters required in GENESIS ensure the influence of each structure is accurately represented in GENESIS modelling. The alongshore location, offshore length, and relative porosity were input for each groin or and the jetties at Indian River Inlet. The offshore location was required for all shore parallel non-erodible barriers (i.e. bulkheads and foundations) that imposed a constraint on the position of the shoreline because it could not move landward. The addition or removal of sediment (beachfills or sand-bypassing) during simulations was specified in GENESIS in terms of volume of material per time period and length of shoreline impacted. The monthly total of sediment bypassed at Indian River Inlet was converted into a constant rate for the time period of the simulation.

82. **Development of a Wave Climate.** Development of a nearshore wave data base for use in the shoreline change model consisted of, first, generating an offshore time series of wave data and then transforming these waves into the nearshore area. The Wave Information Study (WIS) Phase II hindcast data base (Hubertz et al. 1993) were used as a source of deep water wave conditions. The WIS Phase II Station 66, located off of Rehoboth Beach in an approximate water depth of 59 ft, best represented the deep water conditions offshore of the study area. The WIS hindcast provided a 38-year (1956-1993) time series of significant wave height, mean direction of propagation, and peak spectral period at 3-hr time intervals for locally generated wind sea and swell conditions. The second part of the process was done in two steps. The waves were first transformed using the WIS Phase III transformation technique (Jensen 1983) to a depth where irregularities in the bottom topography begin to effect the wave field. The GENESIS support program WAVETRAN was used for this operation. From this depth the waves were propagated shoreward using a numerical model, RCPWAVE, that accounts for irregularities in the nearshore bathymetry.

83. ***Representative Wave Data.*** For simulation periods when there were no hindcast data (forecasting after 1993) a representative wave time series was developed. The overall WIS time series was broken up into individual years and the GENESIS support programs WHEREWAV and SEDTRAN were used to compute average wave and sediment transport conditions for the year. WHEREWAV is used to categorize wave events in the time series by wave period (referred to as "period bands") and direction of propagation (referred to as "angle bands"), and reports various statistical properties of each of the period and angle band categories. SEDTRAN computes longshore transport rates based on water depth, and the wave height, period, and angle with respect to the shoreline. The mean and standard deviation of all of the individual years' average conditions were computed. Wave or sediment transport conditions falling within one standard deviation of the mean conditions were considered representative. Summary tables were developed to determine which years were most representative and which were most extreme for the entire 38 years of WIS hindcast

data and are presented in Section 2 of the Engineering Appendix. A simulation using the most representative wave conditions would expect to produce shoreline configurations most likely to occur in the future. An envelope of possible shorelines may be generated using the more extreme wave conditions.

84. *Nearshore Wave Transformation Analysis.* A wave transformation model that accounts for wave refraction, diffraction, and shoaling over the natural bathymetry was required to obtain an accurate measure of the nearshore wave climate and its variation along the study reach. The numerical model RCPWAVE, which accounts for these effects on linear monochromatic waves, was used to compute wave transformations for representative classes of wave conditions (different wave periods and directions) over the actual nearshore bathymetry.

85. The two-dimensional bathymetry grid used in the RCPWAVE model extended from just south of Indian River Inlet to just north of Cape Henlopen. The alongshore axis of the grid was oriented 354.5 degrees east of north, making it nearly parallel with the general orientation of the project shoreline. The cell size was selected to be small enough to resolve irregularities in the bathymetry that would effect the nearshore transformation. The most recent detailed bathymetry data were obtained from the National Ocean Service Hydrographic Data Base and processed through a grid generation algorithm to develop the bathymetry grid.

86. GENESIS requires pre-breaking wave height, period, angle, and water depth alongshore. A nearshore reference line was established alongshore and was used as the offshore location where nearshore wave information were saved during RCPWAVE simulations. This nearshore reference line was located at the breaking point of the largest waves in the time series, ensuring pre-breaking wave conditions required for GENESIS. Transformed wave information was saved at the RCPWAVE grid cells overlying the nearshore reference line, approximately the 20-ft contour. Wave information at this depth was selected as representative of the nearshore conditions because of its proximity to the shore as well as being deep enough that only the largest of the waves in the time series would have broken or be near breaking at this depth. This nearshore wave data set along the shoreline reach along with the transformed wave time series was used as input into the GENESIS model.

87. **Simulation of Long-Term Shoreline Change.**

88. *Potential Longshore Transport Rates.* Prior to running the shoreline response model GENESIS, estimates of longshore transport were made. Potential left (north) and right (south) sand transport rates were calculated along with the resulting net and gross transport rates for the years 1956 through 1993 using the transformed WIS hindcast wave conditions. These rates can only be considered representative of the region since one representative shoreline orientation and one set of offshore wave conditions were used as input to the calculations.

89. The nearshore wave conditions computed using RCPWAVE, which serve as input to GENESIS, were also used to compute local potential longshore sediment transport. The GENESIS

support program NSTRAN was used to compute the potential longshore sand transport at each RCPWAVE cell. These potential rates represent the local potential conditions and will be used for comparison with those calculated in GENESIS. Summary tables of both the regional and local alongshore potential sand transport rates are provided in Appendix A, Section 2.

90. ***Sediment Budget.*** The wave and sediment transport analyses performed prior to GENESIS calibration aided in the development of a sediment budget for the study. A sediment budget was developed for the northern coast of Delaware to determine the sources, sinks, and volumetric rates of sediment moving in or out of the region. The objective of the budget study was to account for the gain or loss of sediment through time by a study of the various factors that influence sediment erosion, transportation, and deposition in the study area.

91. For this study three major components were analyzed: Longshore Transport, Beach Erosion, and Direct Sources such as Beach Fills or Sand Bypassing. Volumetric rates for each factor are provided for individual reaches as shown in Table 7. The potential longshore transport rates were determined using the GENESIS support program NSTRAN with transformed wave data output from RCPWAVE. Volumetric rates of beach erosion were determined for the individual reaches by multiplying the long-term erosion rates by the vertical distance between the average berm height and the depth of closure for the reach. Historical analysis of sediment sources to the region such as beach fills and sand bypassing provided average volumetric rates supplied to the individual reaches.

TABLE 7
VOLUMETRIC SEDIMENT BUDGET RATES
(000's)

REACH	BEACH EROSION (yd^3/yr)	SAND BYPASSING (yd^3/yr)	POTENTIAL ALONGSHORE TRANSPORT (yd^3/yr)			
			NORTH	SOUTH	NET	GROSS
I	-90.8	0	-453.1	101.7	351.4	554.8
II	-19.4	0	-451.8	114.1	-337.7	565.9
III	-20.7	0	-220.2	162.1	-58.1	382.3
IV	-152.8	0	-518.7	116.3	-402.4	635.0
V	-69.0	115.0[1]	-762.1	136.9	-625.2	899.0

1. Reach V contains Indian River Inlet sand bypassing plant.

92. ***GENESIS Calibration and Verification Strategy.*** The MHW shoreline positions along the project reach from the dates October 1982 and August 1987 were used for calibration of the GENESIS model. These dates were selected because it is desirable to calibrate the GENESIS model between shoreline positions measured at the same time of the year, avoiding seasonal changes in the shoreline position which may effect calibration or verification results. Additional criteria considered include avoiding time periods with major storms and covering time periods similar to what is expected to be used in forecasting.

93. The GENESIS model spanned from Indian River Inlet north to a position south of Cape Henlopen. The cell spacing was chosen to resolve the groins located in Rehoboth and allow smaller spacing of the groins to be analyzed for potential in reducing renourishment rates. Cell one of the model is on the left hand model boundary relative to a person standing on the beach looking seaward, this places cell one near the north end of the project reach.

94. The north and south boundaries of the model are located at a large groin and at Indian River Inlet's northern jetty, respectively. Both boundaries employ a gated boundary condition (Hanson and Kraus 1989). This condition allows for control of sand transport into and out of the modeled shoreline reach by controlling the amount and direction of transport across the model boundary. The structure lengths and permeabilities can also serve as calibration parameters.

95. ***Model Calibration.*** The calibration procedure consists of running the GENESIS model over a time period between two known shorelines (1982 to 1987). Input parameters are adjusted to obtain the best possible agreement between the measured and calculated shorelines. The primary parameters adjusted to obtain agreement are the values of K_1 and K_2, coefficients which control the overall magnitude of sand transport within the shoreline change model. However, because of the large number of groins within the Rehoboth area, adjustment of the permeability of each groin is an important calibration parameter needed to obtain a satisfactory agreement between measured and calculated shorelines.

96. Calibration of the model to accurately represent measured shoreline change has proven to be very demanding. Several potential problems which may be complicating calibration include: 1) current-induced sediment transport caused by the Delaware Bay and Indian River Inlet; 2) poor quality (sparseness) of measured shoreline data; and 3) accurate representation of groins (variable permeability of individual groins).

97. Due to the insufficient calibration agreement and a minimal improvement in the understanding of the regional parameters that effect local transport patterns, it was concluded that the Genesis model would not be utilized in a predictive mode for evaluating the plans of improvement. The model is available for further calibration and verification pending availability of higher quality data/information on regional circulation and shoreline response.

98. **Existing Coastal Structures.** There are at present nine groins within the study limits, all located in Rehoboth Beach. The groins are of stone and timber crib construction at the seaward end

and steel and timber construction along the inner landward section. Six groins were originally constructed in the 1930's , another in 1945 and two others were built in 1962. The groins were rehabilitated in 1950, 1962, and 1968. Prior to the 1930's there were at least four groins in Rehoboth Beach but these have deteriorated over time to the point that they are no longer visible. In the 1970's a timber groin was built just north of the project limit at Deauville; in 1990 a rubble mound structure was built over the existing timber. See Figure 8 for locations. All of the groins were built by the State of Delaware.

99. In general, the groins located in the northern half of Rehoboth Beach were more exposed than the those located towards the southern half. All of the groins visible areas appeared to be in fair condition, with the exception of the three northernmost groins, although they still appeared to be effective in trapping sand. Table 8 presents a summary of the existing groins. Photos of the groins are included in Appendix A, Section 2.

TABLE 8
REHOBOTH BEACH, DELAWARE
EXISTING BEACH GROINS

LOCATION	TYPE OF CONSTRUCTION	LENGTH	CONDITION	YEAR BUILT
Oak Avenue	Timber sheeting & stone filled timber crib	300'	poor	1962
Lake Avenue	Steel sheetpile & stone filled timber crib	294'	poor	1935
Virginia Avenue	Steel sheetpile & stone filled timber crib	293'	poor	1935
Maryland Avenue	Steel sheetpile & stone filled timber crib	298'	fair	1935
Rehoboth Avenue	Steel sheetpile & stone filled timber crib	305'	fair	1945
Delaware Avenue	Steel sheetpile & stone filled timber crib	323'	fair	1935
Laurel Street	Timber sheeting & stone filled timber crib	340'	fair	1962
New Castle Street	Steel sheeting & stone filled timber crib	341'	fair	1935
E. Rodney Street	Steel sheeting & stone filled timber crib	343'	fair	1935

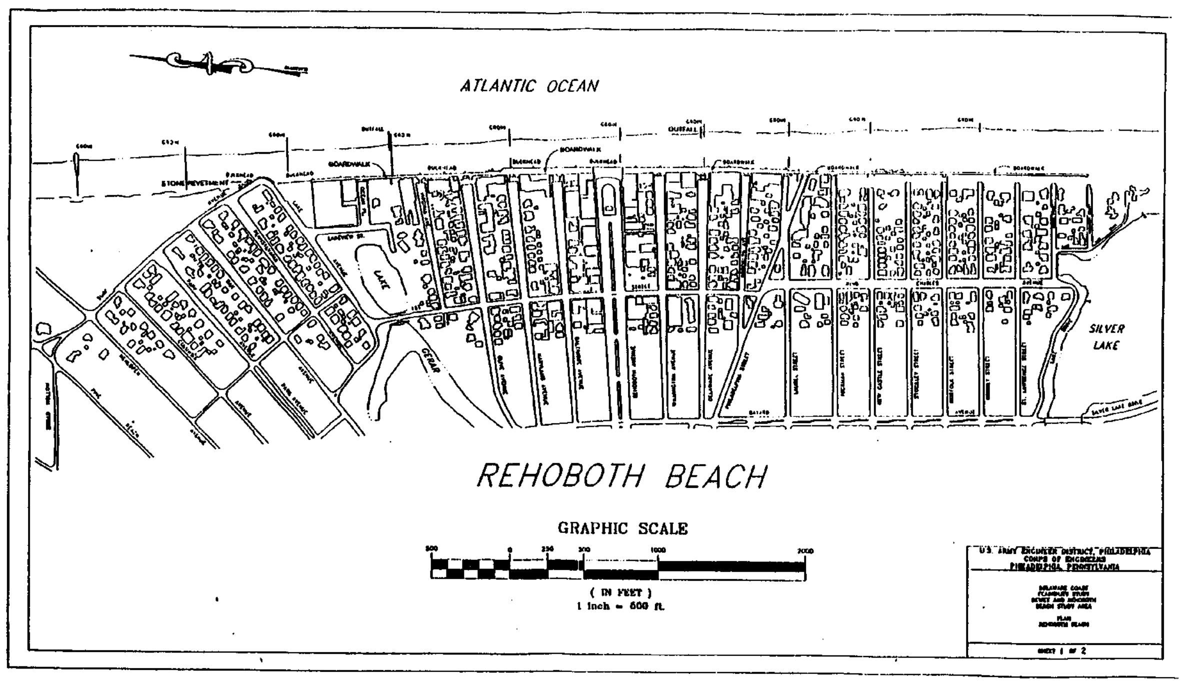

ATLANTIC OCEAN
STONE REVETMENT
BOARDWALK
OUTFALL
SILVER LAKE
LAKE
REHOBOTH BEACH
GRAPHIC SCALE
(IN FEET)
1 inch = 600 ft.

Figure 8

100. In Rehoboth Beach there are five bulkheads protecting approximately 1,150 feet or 17% of the oceanfront. Four of the bulkheads are constructed of timber and one is built of steel sheet piling. These bulkheads were for the most part built by the city and are used to protect street ends. There are seven bulkheads in Dewey Beach and all are constructed of timber. Approximately 1,750 feet or 30% of Dewey is protected with bulkheads. These bulkheads were built by individuals and protect private property. The bulkheads of both towns appeared to be in fair to good condition and were effectively protecting areas landward. However, some of the existing bulkheads are not long enough in length perpendicular to the ocean, and are susceptible to flanking on either side by adjacent eroded areas. See Table 9 for a summary of the bulkheads. Locations are shown in Figures 8 and 9. Photos of the bulkheads are included in Appendix A, Section 2.

101. A stone revetment is located at Surf and Lake Avenues just north of the steel sheetpile bulkhead in Rehoboth Beach. The revetment protects the north side of the bulkhead from flanking and also acts as toe scour protection for the dunes landward. It appears to be in good condition and is effectively working. A more detailed description and photo is included in Appendix A, Section 2.

102. **Storm Drain Outfalls.** Within the study area, currently 3 outfalls extend out to mean low water (Figure 8). These are located at Ocean Place, Delaware Avenue, and at Silver Lake located between Rehoboth Beach and Dewey Beach. These outfalls are constructed on timber piles and extend over 300' to mean low water. These outfalls would not have to be extended for a beachfill project due to the existing length and elevation of the pipes.

103. There are 9 additional outfalls in Rehoboth Beach at street ends located just beneath the boardwalk and 1 at Surf Avenue extending thru the existing steel sheetpile bulkhead. These outfalls are built on timber piles and do not extend seaward of the boardwalk. Therefore, if the selected plan were to include a dune, additional outfalls would have to be extended beyond the dune and beachfill in order to maintain current drainage effectively. However, through an ongoing capital improvement program, the City of Rehoboth Beach has been systematically extending these outfalls. This is being accomplished by combining adjacent outfalls underneath the boardwalk, and then running one main line out to mean low water. This was already performed with the extended outfall at Delaware Ave. which combined with the street end outfalls at Wilmington and Brooklyn Avenues. The local sponsor and the City of Rehoboth Beach have indicated that all outfalls will have been extended prior to the base year. Therefore, the extension of these street end outfalls are being treated as a pre-existing condition.

104. There are no storm drain outfalls located on the beach in Dewey Beach since all drainage structures have their outlets in Rehoboth Bay and, therefore, would not be impacted by any proposed project along the ocean front. A more detailed description and photos of the existing outfalls are included in Appendix A, Section 2.

105. **Boardwalk.** A boardwalk extends from the north end of Rehoboth Beach at Surf Ave. south to Prospect street. The boardwalk varies in width from 15 ft to 45 ft. The boardwalk is of timber construction and one has been present in Rehoboth Beach for many years. In recent times the

boardwalk was rebuilt in the early 1960's and in 1992 following coastal storms. Condition of the boardwalk is good. A more detailed description and photos are included in Appendix A, Section 2.

TABLE 9
REHOBOTH BEACH, DELAWARE
EXISTING BULKHEADS

LOCATION	TYPE OF CONSTRUCTION	LENGTH	CONDITION	YEAR BUILT
Surf and Lake Avenue	Steel sheetpile	150'	fair	not known
Ocean Place	Timber sheeting with king piles	250'	good	1992
Virginia Avenue south side	Timber sheeting with king piles	150'	good	not known
Olive Avenue	Timber sheeting with king piles	100'	good	1992
Rehoboth Avenue	Timber sheeting with king piles	200'	good	1992
Maryland Avenue	Timber sheeting with king piles	300'	good	1992
New Orleans St.	Timber sheeting with king piles	100'	good	1992
Swedes Street north side	Timber sheeting with king piles	200'	good	not known
Clayton Street north side	Timber sheeting with king piles	200'	good	not known
Chicago Street north side	Timber sheeting with king piles	200'	good	not known
Chicago Street south side	Timber sheeting with king piles	100'	good	not known
Carolina & Chesapeake Sts.	Timber sheeting with king piles	700'	good	not known
Mckinley Street south side	Timber sheeting with king piles	250'	good	1992

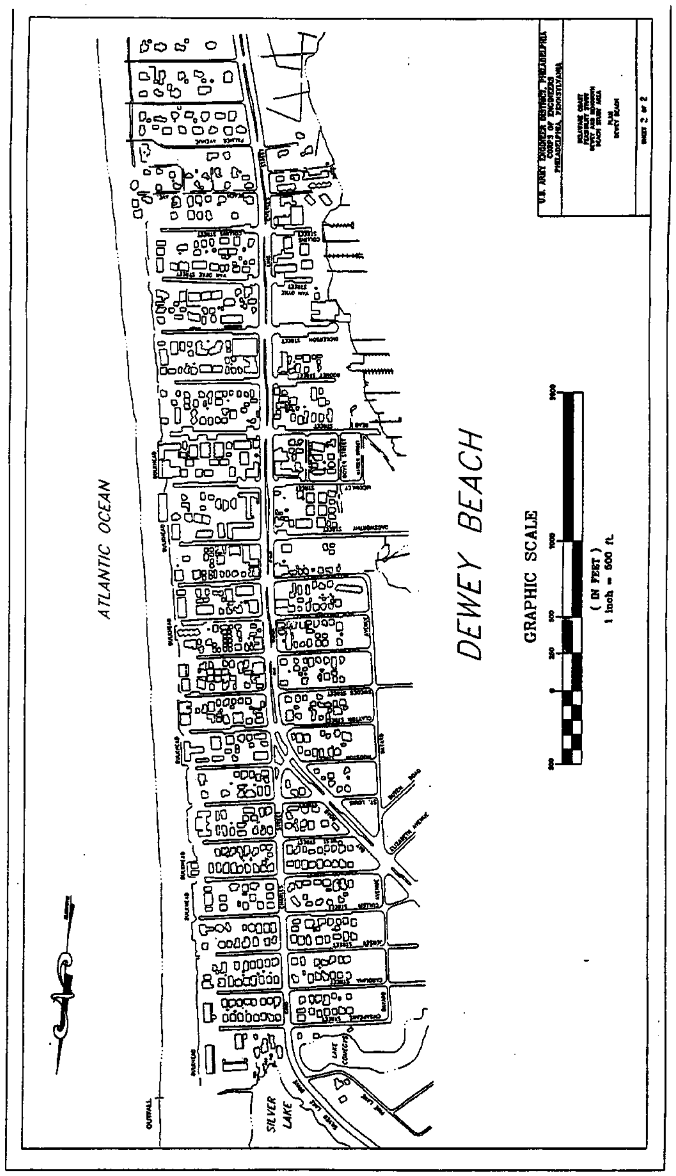

ATLANTIC OCEAN
DEWEY BEACH
GRAPHIC SCALE
(IN FEET)
1 inch = 500 ft.
SILVER LAKE

Figure 9

SOCIAL AND ECONOMIC SETTING

106. **Population and Land Use.** The interim feasibility study area is comprised of Rehoboth Beach and Dewey Beach which lie within the 950 square miles of Sussex County. Sussex County is the southernmost and largest of the three counties in Delaware, encompassing 48% of the state's land. Although it is the largest of the counties it is also the least populated, with only 113,229 year round residents, totaling 17% of the state's permanent population.

107. Rehoboth Beach remains the most developed and heavily populated resort area on the Delaware ocean coast. The beach is lined with high rise hotel and condominium complexes as well as the typical summer cottages. There are a total of 3,105 housing units within the town, of which only 21% are occupied year round. The median value of a single family home in 1990 was $205,000.

108. Rehoboth Beach is heavily developed with very little available land in the city, particularly along the ocean front. However, before any construction can begin, whether it is new construction or rehabilitation, property owners must receive the proper permits from DNREC. DNREC helps the applicant arrange meetings with the appropriate state officials as well as answer any questions on permit requirements. Rehoboth Beach also strictly adheres to the Federal Emergency Management Agency (FEMA) guidelines, and in 1990 delayed the construction of a new hotel between Maryland and Olive Avenues because the proposed basement was in the V-Zone, an area of 100-year coastal flood with velocity (wave action). Rehoboth Beach has a significant V-zone landward of its boardwalk, but beyond the V-zone the flood zone drops to a C, an area of minimal flooding. The building line in Rehoboth Beach starts about 10' landward of the boardwalk at Rodney Street (the south end of the city), and moves to about 25' landward at Philadelphia Street, before moving further inland. At Wilmington Avenue, the building line is 55' landward of the boardwalk, and increases at Maryland to 75' before reaching it's furthest point back at 155' at the north end of the city (Lake Avenue). Presently, about a dozen structures stand seaward of the building line. The structures' foundations along the ocean block are mixed, with most structures built after the March 1962 storm on piles.

109. While there are only 1,234 year-round residents, Rehoboth Beach attracts thousands of summer residents every year with its beaches and its own boardwalk. The boardwalk contains all the associated stores, fast food establishments, arcades and amusement rides. The town provides public access to the municipality's beach, and has many metered parking spaces along with various shuttle services. Still, parking may be difficult on weekends at the height of the tourist season as the population in Rehoboth Beach soars to 100,000 on a typical holiday weekend.

110. The unincorporated area of Silver Lake is directly south of Rehoboth Beach. This area is designated in the Coastal Zone Barrier Act. Presently, 15 houses are planned or being constructed between Silver Lake and the Atlantic Ocean.

111. Similar to Rehoboth Beach, the northern portion of Dewey Beach is backed by headland, but the southern end of Dewey Beach differs greatly in its geography and vulnerability to storm damage.

The southern half of Dewey Beach is situated on a narrow strip of land between the Atlantic Ocean and Rehoboth Bay and is essentially a barrier island. The town of Dewey Beach has become a developed overflow area of Rehoboth Beach, with additional public beach access. Dewey Beach is a changing community where older residences still exist. Over 41% of the population is retired, and although more than half of the current residents have lived in their present homes for the past 15 years, the situation is starting to change. Many of the older properties are being sold, the cottages on them razed, and new modern townhouses built in their place. This is occurring primarily in the southern part of town where it is zoned for multi-family dwellings, however the northern properties remain zoned for single family residences allowing some of the uniqueness to remain in the town.

112. An interesting ownership pattern exists in the single family residential zone on the ocean block. The land in this area was once owned by one family, and about half the lots in the residential area are still owned by this family with the land being leased to the homeowners for 50 years. The homeowners still own their house but not the land its built on. This is true even for some of the multi-family dwellings such as the Sea Strand complex on Carolina and Chesapeake Streets. The family operates under the business name of Rehoboth By the Sea Realty, who manages all the leases. Commercial properties are allowed along Highway One, and some along Rehoboth Bay. No new construction is allowed beyond 30' inland from the center line of Dewey Beach's dunes per town ordinance. This regulation is more strict than FEMA's guidelines.

113. According to the U.S. Census Bureau, the permanent population of Dewey Beach is 204, however, the summer population can rise to 35,000 on a typical holiday weekend. Dewey Beach has no property tax base. All revenues come from parking permits, traffic tickets, building permits and realty transfer fees. Delaware State Route One provides the sole means of access to both Rehoboth Beach and Dewey Beach. The largest portion of vacationers attracted to both communities are those staying overnight but less than a week.

114. Both the State of Delaware and Sussex County are projected to increase in population over the next twenty years, but at a decreasing rate of growth. Sussex County is growing faster than the state of Delaware as a whole. Table 10 contains estimates of population by the Delaware Population Consortium, University of Delaware, College of Urban Affairs and Public Policy.

TABLE 10
TOTAL POPULATION

	1985	1990	1995	2000	2005	2010
Delaware	625,950	682,700	738,150	784,850	820,500	845,000
Sussex County	107,450	121,050	132,400	142,700	151,700	162,350

115. **Economic Development.** The Delaware Population Consortium projected the labor force in Sussex County to be 62,750, with 60,850 employed in 1990. The unemployment rate in Sussex County was 4.2% in May 1990, compared with a 5.1% unemployment rate at the state level. The study area differs from the rest of Sussex County, and Delaware, in its reliance on the tourism industry rather than agriculture and manufacturing/processing. In Sussex County, 1/3 of those employed in the county are in retail or services, while another 1/3 are in manufacturing. The coastal study area is devoid of manufacturing, relying almost 100% on the service/retail industry. Despite this dependency on the tourist industry both Rehoboth Beach and Dewey Beach continue to display extremely low unemployment rates and high median household incomes. Despite nationwide growth in unemployment, and a constant decline in median household incomes, Rehoboth Beach remained well above the national average with only 4.3% unemployment and a median income of $31,538, one of the highest in Delaware. Dewey Beach also had a median household income of $16,364 and an almost unheard of unemployment rate of 0%.

116. The estimated per capita income in 1990 was $12,723 for Sussex County. As shown in Table 11, the coastal resort communities are considerably better off than the rest of Sussex County. Even when economically hard times hit the State's economy (particularly poor agricultural crops or recession in the manufacturing industry), the economy of the Delaware coast should remain buoyant as it serves as a summer resort for the residents of our Nation's Capitol and other urban and suburban areas.

TABLE 11
PER CAPITA INCOME

NAME	PER CAPITA INCOME 1990 est.
United States	$16, 257
Delaware	$17,474
Sussex County	$12,723
Rehoboth Beach	$20,734
Dewey Beach	$16,131

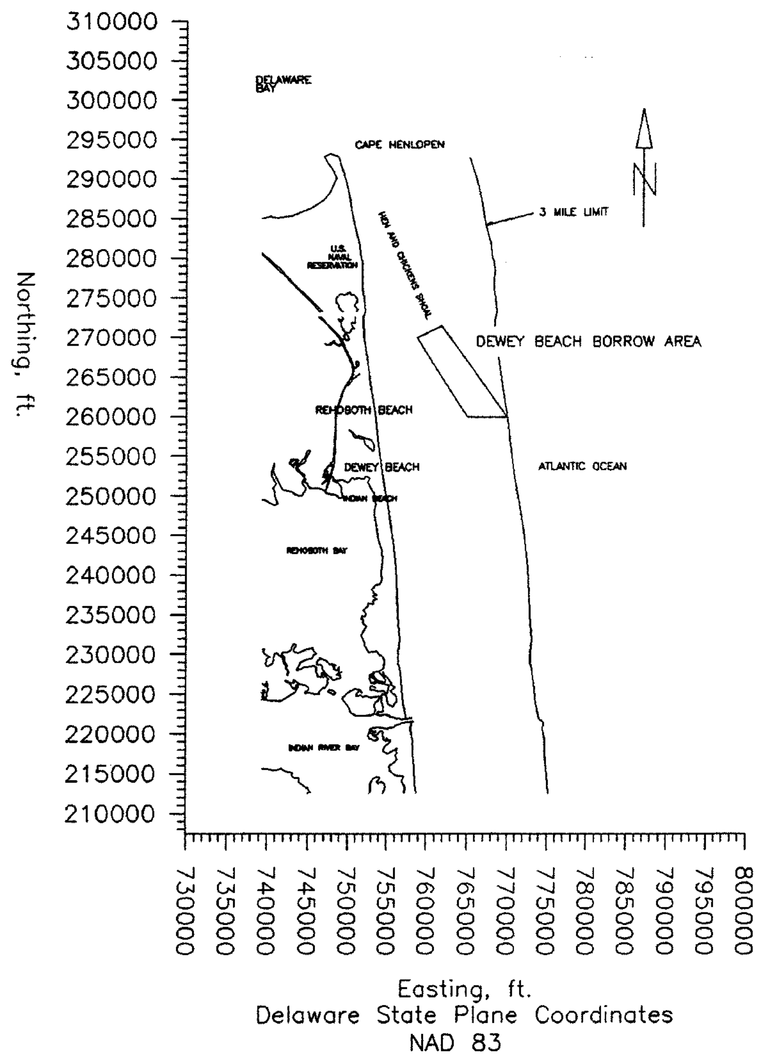
Source: 1992 City and County Data Book published by the U.S. Census Bureau

EXISTING ENVIRONMENTAL CONDITIONS

117. **The Study Area.** The northern portion of the Delaware Atlantic Ocean coast contains a spit-headland complex, baymouth barrier beaches, inland bays, tidal marshes, and Atlantic Coastal Waters. The study area principally involves the Rehoboth Beach/Dewey Beach area along the Delaware ocean coast, which extend for a distance of approximately 2 miles north to south and an offshore sand borrow area on Hen and Chickens Shoal (Figures 2 and 10). The beachfront within these limits is densely developed with houses, stores, and boardwalks with the exception of the Silver Lake area and an area at the northern terminus of the project (Deauville). Because of the high development within the project area, the beach is frequently disturbed by human activities centered around recreation. In Rehoboth Beach, the beach, for the most part, lacks a natural dune system due to extensive development. Dunes in Dewey Beach are non-existent due to recent storm events and high development.

118. **Water Quality of Delaware Atlantic Coastal Waters.**

119. ***Temperature and Salinity.*** Mixing occurs in nearshore waters due to the turbulence created from wave energy interacting with the bottom at shallower depths. Mixing becomes less prominent in greater depths where stratification can develop during warm periods. Water temperatures generally fluctuate seasonally. The average temperature range is from 3.7O°C (January) to 21.4°C (October). The most pronounced temperature differences are found in the winter and summer months. Warming of coastal waters first becomes apparent near the coast in early spring, and by the end of April, thermal stratification may develop. Under conditions of high solar radiation and light winds, the water column becomes more strongly stratified during the months of July to September. The mixed layer may extend to a depth of only 12 to 13 feet. As warming continues, however, the thermocline may be depressed so that the upper layer of warm, mixed water extends to a depth of approximately 40 feet. Salinity concentration is chiefly affected by freshwater dilution. Salinity cycles result from the cyclic flow of streams and intrusions of continental slope water from far offshore onto the shelf. Continental shelf waters are the least affected by freshwater dilution, and have salinity concentrations varying between 30 parts per thousand (ppt) and 35 ppt. Coastal waters are more impacted by freshwater dilution and may have salinities as low as 27 ppt. Salinity is generally at its maximum at the end of winter. The voluminous discharge of fresh water from the land in spring reduces salinity to its minimum by early summer. Surface salinity increases in autumn when intrusions from offshore more than counterbalance the inflow of river water and when horizontal mixing becomes more active as horizontal stability is reduced. At Hen and Chicken Shoal, Maurer et al., 1974 states that salinity fluctuates little throughout the tidal cycle, depth, and between sampling stations, and was found to range from 27.2 ppt (April) to 29.8 ppt (October). Mean dissolved oxygen values at Hen and Chicken Shoal were 3.68 ppm (January) to 8.01 ppm (August) (Maurer et al., 1974). Recent water sampling was conducted within the proposed sand borrow site just above the substrate in depths ranging from 23.0 ft to 31 ft. The average temperature was 14.2°C and the average dissolved oxygen and salinities were 8.43 mg/L and 32.3 ppt, respectively (Dames and Moore, 1993).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ATLANTIC OCEAN
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765000
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785000
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Easting, ft.
Delaware State Plane Coordinates
NAD 83

Figure 10

120. ***Water and Sediment Quality Parameters.*** Water quality is generally good in the nearshore because of the constant circulation provided by waves and currents. In 1973-74, water quality was sampled at three stations in Hen and Chickens Shoal by DNREC (Maurer et al., 1974). No general patterns regarding site locations, seasons, night-day, and state-of-the tide emerged from the data. The highest concentrations of heavy metals were silver (0.06-0.14 ppm), lead (<0.1-0.38 ppm), and nickel (<0.1-0.21 ppm). Arsenic levels were below 0.04 ppm. Ammonia nitrogen ranged from 1.6-5.5 ppm.

121. Beach closings occasionally occur due to high coliform levels usually after high rainfall events. Rehoboth Beach has the most frequent beach closings due to a high concentration of storm sewer outfalls which discharge on the beach. The State of Delaware Division of Public Health frequently monitors water quality for recreation between the months of May through September. No beach closings or swimmer advisories were issued between 1992 and 1994 for Rehoboth Beach and Dewey Beach (Pingree,1994).

122. Sediments in the borrow area are composed of medium to fine sands with very low amounts of silts and clays. Organic contaminants and metals are typically low in sediments dominated by sands. Therefore, it is expected that the borrow area is not chemically contaminated because the substrate is primarily sand that has been subjected to a high energy-current regime. This coupled with the absence of dumping activities, industrial outfalls, or contaminated water suggest a low probability of sediment contamination.

123. **Terrestrial Ecology of Study Area.** The entire project area contains a high energy beach with land features such as headland in the north (Rehoboth Beach and northern Dewey Beach) and barrier island to the south (middle and southern Dewey Beach). The barrier island is flanked on the west by Rehoboth Bay and the Atlantic Ocean on the east. Primary and secondary dunes are basically non-existent throughout the majority of the project area due to high development and erosion. Exceptions to this are at Silver Lake and the northern terminus of the project area at Deauville just north of the bend in Lakeshore Drive in Rehoboth Beach. In 1994, construction of several single-family homes began immediately behind the primary dune at Silver Lake.

124. ***Beach and Dunes.*** Although typical beach dunes and the habitats associated with them are either fragmented and highly disturbed or are non-existent within the project area, a few elements of beach dune flora and fauna are still present. The largest stretch of undeveloped beachfront exists at the northern end of the project area at Deauville which extends for approximately 2,800 feet. The beaches of Cape Henlopen State Park and Delaware Seashore State Park exhibit unfragmented natural settings where typical dune flora and fauna are present. The following discussion on beach dunes mainly pertains to surrounding areas outside of the Dewey Beach and Rehoboth Beach study area, however, some of the dune flora and fauna discussed may still be present in limited pockets in the study area.

125. In typical undisturbed beach profiles of the Delaware Atlantic Coast, the primary dune is the first dune landward from the beach. The flora of the primary dune are adapted to the harsh conditions

present such as low fertility, heat, and high energy from the ocean and wind. The dominant plant on these dunes is American beach grass *(Ammophila breviligulata)*, which is tolerant to salt spray, shifting sands and temperature extremes. American beach grass is a rapid colonizer that can spread by horizontal rhizomes, and also has fibrous roots that can descend to depths of 3 feet to reach moisture. Beach grass is instrumental in the development of dune stability which opens up the dune to further colonization with more species like seaside goldenrod *(Solidago sempervirens)*), sea-rocket *(Cakile edentula)* and beach clotbur *(Xanthium echinatum)*.

126. The secondary dunes lie landward of the primary dunes, and tend to be more stable resulting from the protection provided by the primary dunes. The increased stability also allows an increase in plant species diversity. Some of the plant species in this zone include: beach heather *(Hudsonia tomentosa)*, coastal panic grass *(Panicum amarum)*, saltmeadow hay *(Spartina patens)*, broom sedge *(Andropogon virginicus)*, beach plum *(Prunus maritima)*, seabeach evening primrose *(Oenothera humifusa)*, sand spur *(Cenchrus tribuloides)*, seaside spurge *(Ephorbia polygonifolia)*, joint-weed *(Polygonella articulata)*, slender-leaved goldenrod *(Solidago tenuifolia)*, and prickly pear *(Opuntia humifusa)*.

127. Along undeveloped portions of the Atlantic Ocean coast of Delaware, the primary and secondary dunes grade into a zone of shrubby vegetation. These zones are typically located on the headlands or on the barrier flats of the barrier beaches. This zone is called the scrub-thicket zone where sand movement is more diminished. Many of the flora are dwarf trees and shrubs which include: wax-myrtle *(Myrica cerifera)*, bayberry *(M. pennsylvanica)*, dwarf sumac *(Rhus copallina)*, poison ivy *(Toxicodendron radicans)*, black cherry *(Prunus serotina)*, American holly *(Ilex opaca)*, greenbrier *(Smilax spp.)*, groundsel bush *(Baccharis halimifolia)*, loblolly pine *(Pinus taeda)*, pitch pine *(Pinus rigida)*, Virginia creeper *(Parthenocissus quinquefolia)*, beach plum *(Prunus maritima)*, and the non-native Japanese black pine *(Pinus thunbergii)*.

128. A number of non-marine mammals, reptiles, amphibians and birds are associated with the dune habitat along the Delaware coastline. These species include: Fowler's toad *(Bufo woodhousei fowleri)*, eastern hognose snake *(Heterodon platyrhinos)*, box turtle *(Terrapene carolina)*, raccoon *(Procyon lotor)*, eastern cottontail *(Sylvilagus floridanus)*, red fox *(Vulpes fulva)*, white-footed mouse *(Peromyscus leucopus)*, meadow vole *(Microtus pennsylvanicus)*, white-tailed deer *(Odocoileus virginianus)*, savannah sparrow *(Passerculus sandwichensis)*, song sparrow *(Melospiza melodia)*, mourning dove *(Zenaida macroura)*, gray catbird *(Dumetella carolinensis)*, northern mockingbird *(Mimus polyglottos)*, and brown thrasher *(Toxostoma rufum)*.

129. Several freshwater wetland pockets have formed within interdunal swales at Cape Henlopen State Park, Delaware Seashore State Park, and a short stretch of beach just north of Bethany Beach. These wetlands contain rare and unique plant communities which include cranberry *(Vaccinium macrocarpon)* and sundew *(Drosera sp.)*. No interdunal wetlands are present within the project area.

130. The upper beach or supralittoral zone typically lies below the primary dune and above the intertidal zone. An upper beach zone is present within the study area, however, it is subject to high

disturbance from human activity. The upper beach zone is only covered with water during periods of extremely high tides and large storm waves. The upper beach habitat is characterized by sparse vegetation and few animals. This zone has fewer biological interactions than the dunes, and organic inputs are scarce. The most active organism in this zone is the ghost crab *(Ocypode quadrata)*. This crab lives in semi-permanent burrows near the top of the shore, and it is known to be a scavenger, predator, and deposit sorter. The ghost crab is nocturnal in its foraging activities, and it remains in its burrow during the day. In addition to ghost crabs, species of sand fleas or amphipods (Talitridae), predatory and scavenger beetles and other transient animals may be found in this zone.

131. Many species of shorebirds inhabit the beach during the spring and fall migrations, although most are even more likely to be found on more protected sand and mud flats, tidal marshes, or along the Delaware Bay shoreline (especially in spring when large numbers of horseshoe crab eggs are available). Shorebirds feed on small individuals of the resident infauna and other small organisms brought in with waves. Common shorebird species include sanderling *(Calidris alba)*, dunlin *(C. alpina)*, semipalmated sandpiper *(C. pusilla)*, western sandpiper *(C. mauri)*, and willet *(Catoptrophorus semipalmatus)*. Sanderling, dunlin, and western sandpiper also occur on the beach throughout the winter. Colonial nesting shorebird habitat is increasingly under pressure from development and human disturbance along Delaware's Atlantic beaches. Nesting birds such as common tern *(Sterna hirundo)*, least tern *(S. antillarum)*, black skimmer *(Rynchops niger)* and American oyster catcher *(Haematopus palliatus)* are frequent spring and summer inhabitants on unvegetated dunes and upper beaches at Cape Henlopen and Delaware Seashore State Parks. Undeveloped beaches such as these State Parks are critical for nesting pairs of the Federal and State threatened piping plover *(Charadrius melodus)*. High beachfront development and human disturbance in the Dewey Beach and Rehoboth Beach project area has consequently forced nesting shorebirds to seek the remaining undeveloped beaches.

132. Several species of gulls are common along Delaware's shores, and are attracted to forage on components of the beach wrack such as carrion and plant parts. These gulls include the laughing gull *(Larus atricilla)*, herring gull *(L. argentatus)*, and ring-billed gull *(L. delawarensis)*.

133. **Aquatic Ecology of Affected Area.**

134. *Upper Marine Intertidal Zone.* The upper marine intertidal zone is also primarily barren, however, more biological activity is present in comparison to the upper beach. Organic inputs are derived primarily from the ocean in the form of beach wrack, which is composed of drying seaweed, tidal marsh plant debris, decaying marine animals, and miscellaneous debris that washed up and deposited on the beach. The beach wrack provides a cooler, moist microhabitat suitable to crustaceans such as the amphipods: *Orchestia spp.* and *Talorchestia spp.*, which are also known as beach fleas. Beach fleas are important prey to ghost crabs. Various foraging birds and some mammals are attracted to the beach fleas, ghost crabs, carrion and plant parts that are commonly found in beach wrack. The birds include gulls, shorebirds, fish crows, and grackles.

135. ***Intertidal Zone.*** The intertidal zone contains more intensive biological activity than the other

zones. Shifting sand and pounding surf dominate a habitat which is inhabited by a specialized fauna. The beach fauna forms an extensive food-filtering system which removes detritus, dissolved materials, plankton, and larger organisms from in-rushing water. The organisms inhabiting the beach intertidal zone have evolved special locomotory, respiratory, and morphological adaptations which enable them to survive in this extreme habitat. Organisms of this zone are agile, mobile, and capable of resisting long periods of environmental stress. Most are excellent and rapid burrowers. Frequent inundation of water provides suitable habitat for benthic infauna, however, there may be a paucity in numbers of species. Intertidal benthic organisms tend to have a high rate of reproduction and a short (1 to 2 years) life span (Hurme and Pullen, 1988). This zone contains an admixture of herbivores, primary carnivores, and some high order carnivores such as the mole crab *(Emerita sp.)*. A number of interstitial animals (meiofauna) are present feeding among the sand grains for bacteria and unicellular algae, which are important in the beach food chain. In 1978, extensive sampling for invertebrate infauna was performed by the U.S. Fish and Wildlife Service and Corps of Engineers on the beaches within the Delmarva Peninsula, Maryland. There were four dominant species of invertebrate infauna in this zone, which were the mole crab *(Emerita talpoida)*, a haustorid amphipod *(Haustorius canadensis)*, the coquina clam *(Donax variabillis)*, and spionid worm *(Scolelepis squamata)*. The epifaunal blue crab *(Callinectes sapidus)* and the lady crab *(Ovalipes ocellatus)* were also found in or near this zone. These species withdraw to the nearshore subtidal zone during the winter months and return to the intertidal zone when conditions are more favorable. These invertebrates are prey to various shorebirds and nearshore fishes such as the Atlantic silverside *(Menidia menidia)*, and juveniles of spot *(Leiostomus xanthurus)*, kingfish *(Menticirrhus saxatilus)*, and bluefish *(Pomatomus saltatrix)*.

136. Benthic macroalgae grow attached to the bottom substrate in the intertidal zone where they are alternately exposed and submerged as the tides ebb and flow. The substrate along the Delaware Atlantic Coast is mainly composed of shifting sands and shell fragments making it too unstable for large colonies of benthic algae to proliferate. Colonies do attach on hard, stable substrates provided by peat banks, shell bottoms, reefs, and man-made structures such as pilings, jetties, buoys and bridges. Various species of benthic macroalgae representing the Phyla Chlorophyta and Phaeophyta are found in Delaware's coastal waters.

137. The nine rock groins in Rehoboth Beach represent an artificial rocky intertidal zone. In addition to providing a hard substrate for the attachment of benthic macroalgae, the groins also contain suitable habitats for a number of aquatic and avian species. Barnacles, small crustaceans, polychaetes, molluscs and a variety of shorebirds may reside on, above and around these structures. Mussels *(Mytilus sp.)* are prevalent on the rock surfaces. These structures are also used by various finfish for feeding and shelter.

138. ***Nearshore and Offshore Zones.*** The nearshore coastal zone generally extends seaward from the subtidal zone to well beyond the breaker zone (U.S. Army Corps of Engineers, 1984). This zone is characterized by intense wave energies that displace and transport coastal sediments. The offshore zone generally lies beyond the breakers and is a flat zone of variable width extending to the seaward edge of the Continental Shelf. Hurme and Pullen (1988) describe the nearshore zone as an indefinite

area that includes parts of the surf and offshore areas affected by nearshore currents. The boundaries of these zones may vary depending on relative depths and wave heights present. From Rehoboth Beach, the nearshore bottom gently slopes to a flat bottom (approx. 9 m) and then rises on Hen and Chickens Shoal. The water depths within the nearshore zone reach a maximum of -60 feet. An exception to this depth is the presence of a deep trough which is a remnant of the ancient Delaware River Channel. Prominent shoal complexes usually occur within the nearshore zone. Hen and Chickens Shoal is located southeast from Cape Henlopen and is formed by ebb tide currents carrying and depositing sands from the lower Delaware Bay (USFWS, 1991).

139. The Delaware Atlantic Coast is rich in planktonic, nektonic and benthic biological resources, which may overlap nearshore waters with offshore waters. The proposed sand borrow site on Hen and Chickens Shoal will be referred to as the proposed offshore borrow site.

140. ***Plankton.*** The Delaware coastal waters contain a diverse assemblage of plankton. Plankton are collectively a group of interacting minute organisms adrift in the water column. Plankton are commonly broken into two main categories: phytoplankton (plant kingdom) and zooplankton (animal kingdom).

141. Phytoplankton play an essential role in the food web because they are the primary producers in the aquatic marine ecosystem. Phytoplankton convert light and chemical energy into organic compounds which can be assimilated by higher organisms in the food chain. Phytoplankton production is dependent on light penetration, available nutrients, temperature and wind stress. Phytoplankton production is generally highest in nearshore waters. Seasonal shifts in species dominance of phytoplankton are frequent. Dinoflagellates are generally abundant from summer through fall and diatoms are dominant during the winter and early spring. Approximately 126 species of phytoplankton were identified in Delaware's coastal waters representing the following Phyla: Chlorophyta, Chromophyta, Pyrrophyta, Euglenophyta, and Procaryota. The most prevalent species and their season of dominance are as follows:

Nitzschia seriata - winter
Skeletonema costatum - late winter, early spring
Guinarkia flaccida - spring
Pyramimonas sp. - spring, early summer
Cryptomonas acuta - summer
Katodinium rotundatum - mid-summer
Chrysochromulina sp. - summer

142. Zooplankton provide an essential trophic link between primary producers and higher organisms. Zooplankton represent the animals (vertebrates and invertebrates) that are adrift in the water column, and are generally unable to move against major ocean currents. Many organisms may be zooplankton at early stages in their respective life cycles only to be able to swim against the currents (nektonic) in a later life stage, or to be a part of the benthic community. Zooplankton are generally either microscopic or barely visible to the naked eye. Zooplankton typically exhibit seasonal

variances in species abundance and distribution, which may be attributed to temperature, salinity and food availability. In marine environments, seasonal peaks in abundance of zooplankton distinctly correlate with seasonal phytoplankton peaks. These peaks usually occur in the spring and fall. Sampling in the lower Delaware Bay by Watling and Maurer (1976) revealed the presence of 60 species representing the following Phyla: Protozoa, Cnidaria, Ctenophora, Ectoprocta, Annelida, Mollusca, Arthropoda, Chaetognatha and Chordata. Calanoid copepods are a dominant component of the zooplankton in Delaware coastal waters (Dupont et al.,1972). Peaks in calanoid copepod dominance are known to occur during October-November, which may be attributed to the high phytoplankton productivity. Zooplankton species characteristic of coastal areas include: *Arcatia tonsa, Centropages humatus, C. furatus, Temora longicornis, Tortanus discaudatus, Eucalanus pileatus, Mysidopsis bigelowi* (mysid shrimp), and *Crangon septemspinosa* (sand shrimp).

143. ***Macroinvertebrates.*** The nearshore and offshore waters of the Delaware Coast contain a wide assemblage of invertebrate species inhabiting the benthic substrate and open water. Invertebrate Phyla existing along the coast are represented by Cnidaria (corals, anemones, jellyfish), Platyhelminthes (flatworms), Nemertinea (ribbon worms), Nematoda (roundworms), Bryozoa, Mollusca (chitons, clams, mussels, etc.) Echinodermata (sea urchins, sea cucumbers, sand dollars, starfish), and the Urochordata (tunicates).

144. Benthic macroinvertebrates are those dwelling in the substrate (infauna) or on the substrate (epifauna). Benthic invertebrates are an important link in the aquatic food chain, and provide a food source for most fishes. Various factors such as hydrography, sediment type, depth, temperature, irregular patterns of recruitment and biotic interactions (predation and competition) may influence species dominance in benthic communities. Benthic assemblages in Delaware coastal waters exhibit seasonal and spatial variability. Generally, coarse sandy sediments are inhabited by filter feeders and areas of soft silt or mud are more utilized by deposit feeders.

145. Hen and Chickens Shoal is a dynamic, heterogeneous area heavily influenced by the tidal flow from Delaware Bay. Although several pockets of fine materials are present, Hen and Chickens Shoal is generally composed of medium to fine sands, which influence the composition of the benthic assemblage. The following benthic species were found to be most abundant in the nearshore waters off of Cape Henlopen by Leathem et al. (1983): *Aricidea catherinae* (paraonid polychaeta), *Spiophanes bombyx* (spionid polychaeta), *Tellina agilis* (tellinid bivalvia), *Mediomastus ambiseta* (capitellid polychaeta), *Brania wellfleetensis* (syllid polychaeta), *Nephtys picta* (nephtyid polychaeta), *Unciola irrorata* (aorid amphipoda), *Paranaitis speciosa* (phyllodocid polychaeta), *Nucula annulata* (nuculid bivalvia), and *Ensis directus* (solenid bivalvia). Maurer et al., 1974 recorded a total of 168 species obtained from quarterly sampling at Hen and Chickens Shoal. The amphipod *(Parahaustorius longimerus)* was the dominant species with lesser numbers of other haustorid amphipods and the molluscs: surf clam *(Spisula solidissima)* and *(Tellina agillis)*. High numbers of blue mussels *(Mytilus edulis)* and a fringed worm *(Tharyx acutus)* were abundant in samples obtained from deep-water stations east of the shoal. These deep-water stations contained hard bottoms composed of coarse sand and pebbles with extensive shell debris and small silt pockets.

146. In June 1993, a benthic-sediment assessment focussing on infauna species was conducted in the proposed offshore sand borrow site located on Hen and Chickens Shoal to establish a baseline for the benthic macroinvertebrate assemblages within the proposed borrow site. Other objectives were to identify the presence of any commercial and/or recreational benthic macroinvertebrates, and to identify the presence of ecologically important benthic communities within the proposed sand borrow site. Two control areas were situated north and south of the proposed sand borrow site to offer comparisons with the data. Figure 11 identifies the sample locations in relation to the proposed borrow site. The sediments inhabited by the benthic community were primarily composed of medium sands (>0.25 mm but <0.43 mm) with the exception of three stations, which were dominated by fine sands (>0.15 mm but <0.25 mm) Although the sampling only represented the benthic assemblage at a single point in time, a total of sixty-three species were identified at the species-level out of a total of 82 taxa. Several species were dominant based on their frequency of occurrence per study area within the borrow site. These species are: *Protohaustorius wigleyi* (haustorid amphipod), *Chiridotea turtsi* (isopod), *Parahaustorius sp.*, *Tellina agilis* (bivalve), and *Nephtys bucera* (polychaete). *Spisula solidissima*, the surf clam, was the only commercial shellfish species identified from the benthic assessment on Hen and Chickens Shoal. The samples in the borrow site generally showed that mean organism density and mean number of taxa was intermediate between the control north and control south. These values were generally highest in control south and lowest in control north. Based on this assessment, organism density, number of taxa, and wet weight biomass per unit area is generally lower compared to other offshore areas in the mid-Atlantic region. The sampling recovered no commercially viable densities of commercial size shellfish or unique benthic assemblages within the study area (Dames and Moore, 1993).

147. ***Finfish.*** The proximity of several embayments allows the coastal waters of Delaware to have a productive fishery. Many species utilize the estuaries of Delaware Bay, Rehoboth Bay and Indian River Bay for forage and nursery grounds. The finfish found along the Delaware Atlantic coast are principally seasonal migrants. Winter is a time of low abundance and diversity as most species leave the area for warmer waters offshore and southward. During the spring, increasing numbers of fish are attracted to the Delaware Atlantic coast because of its proximity to several estuaries which are utilized by these fish for spawning and nurseries. Peaks in the numbers of fish species generally occur in the fall, however, Maurer et al. (1974) noted that fish abundance was greatest at Hen and Chickens Shoal during spring and summer, which indicates that Hen and Chickens Shoal is an important habitat or corridor to Delaware Bay for commercial and sport fish.

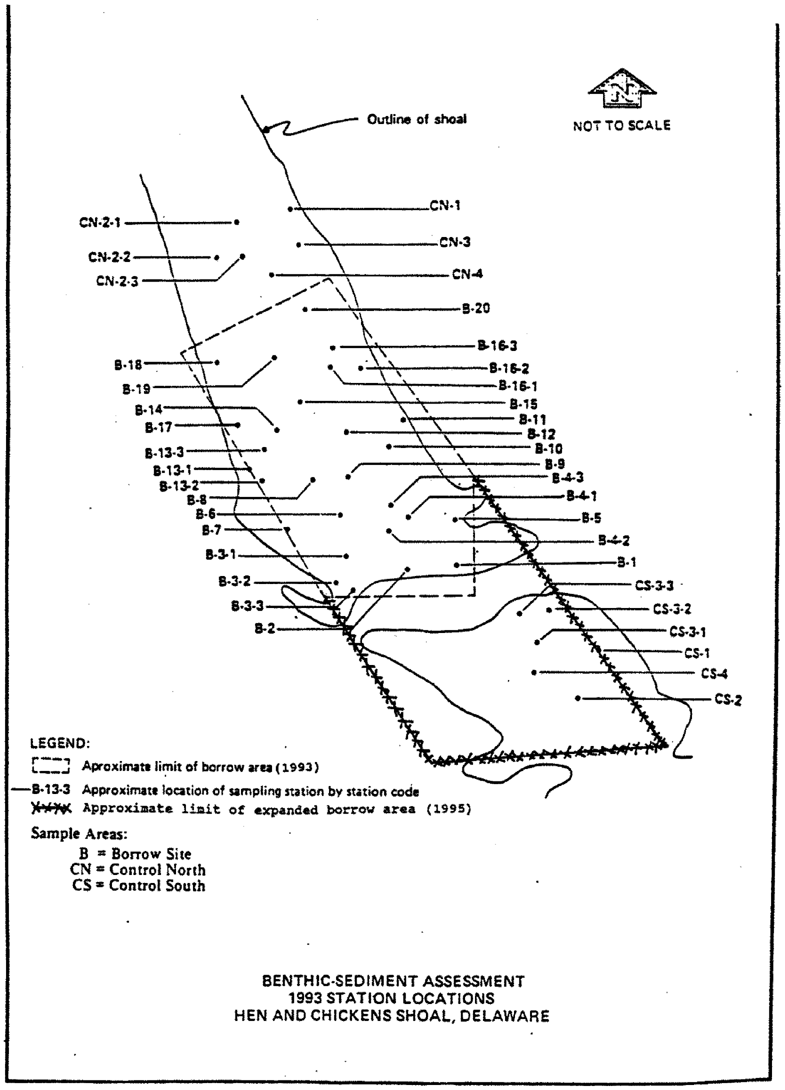

Outline of shoal
NOT TO SCALE
CN-1
CN-2-1
CN-3
CN-2-2
CN-2-3
CN-4
B-20
B-16-3
B-18
B-16-2
B-19
B-16-1
B-15
B-14
B-11
B-17
B-12
B-10
B-13-3
B-9
B-13-1
B-4-3
B-13-2
B-4-1
B-8
B-6
B-5
B-7
B-4-2
B-3-1
B-1
B-3-2
CS-3-3
B-3-3
CS-3-2
B-2
CS-3-1
CS-1
CS-4
CS-2
LEGEND:
Aproximate limit of borrow area (1993)
B-13-3 Approximate location of sampling station by station code
Approximate limit of expanded borrow area (1995)
Sample Areas:
B = Borrow Site
CN = Control North
CS = Control South
BENTHIC-SEDIMENT ASSESSMENT
1993 STATION LOCATIONS
HEN AND CHICKENS SHOAL, DELAWARE

Figure 11

148. Surveys of the finfish in Delaware's coastal waters have been conducted by Maurer and Tinsman (1980), and annually for several years by the National Marine Fisheries Service. Abundant finfish species in Delaware coastal waters include: red hake *(Urophycis chuss)*, northern sea robin *(Prionotus carolinus)*, spot *(Leiostomus xanthurus)*, windowpane flounder *(Scopthalmus aquosus)*, silver hake *(Merluccuns bilinearis)*, clearnose skate *(Raja eglanteria)*, hogchoker *(Trinectes maculatus)*, and weakfish *(Cynoscion regalus)*. Large numbers of bay anchovies *(Anchoa mitchilli)*, butterfish *(Peprilus triacanthus)*, scup *(Stenotomus chrysops)*, weakfish, striped anchovy *(Anchoa hepsetus)*, spot, and bluefish *(Pomatomus saltatrix)*. These surveys, however, do not include habitats associated with any bottom structures like breakwaters, rock jetties and groins, rough bottom off of Cape Henlopen, submerged wrecks and artificial reefs. The following species are more associated with these structures: tautog *(Tautoga onitis)*, gray triggerfish *(Balistes capriscus)*, oyster toadfish *(Opsanus tau)*, conger eel *(Conger oceanicus)*, cunner *(Tantogolabrus adspersus)*, and planehead filefish *(Monacanthus hispidus)* (Ekland, 1987).

149. The numbers of fishes along the Delaware Atlantic Coast are generally not sufficient to support a significant commercial fishing industry, however, the Delaware coast supports a diverse recreational fishery. Approximately 70% of Delaware's shore-based fishing is along the Atlantic coast beaches and jetties (Seagraves, 1988). There are also many private/charter boat fisherman from Indian River Inlet and Lewes that fish the coastal area. The species caught usually include: bluefish, weakfish, croaker, spot, kingfish, red drum, tautog, summer flounder, striped bass, scup, sharks, hakes, sea bass, Atlantic and Spanish mackerel, triggerfish, and blowfish. A sea bass pot fishery and early spring gill net fishing targeting shad and weakfish are the only prevalent commercial fishing operations in the coastal waters of Delaware.

150. ***Shellfish.*** The surf clam has been periodically harvested from Delaware's coastal waters for commercial purposes. The surf clam has a wide distribution and abundance within the mid-Atlantic Region. They most commonly inhabit substrates composed of medium to coarse sand and gravel in turbulent waters just beyond the breaker zone. The abundance of adults varies from loose, evenly distributed aggregations to patchy, dense aggregations in the substrate (Fay, 1983).

151. A peak in harvesting within Delaware's coastal waters occurred in the early 1970's where annual landings exceeded 8.5 million pounds worth approximately $1.1 million. Shortly afterward, the stock experienced a rapid and severe decline, and by 1975, commercial harvesting had ceased. There has been no significant harvesting since then. The dominant 1976 year-class which supports New Jersey's inshore fishery, did not occur in Delaware waters. Surveys conducted by the State in 1982, 1986, and 1992 confirmed that no significant numbers of commercial sized surfclams exist within Delaware's three-mile territorial limit (Tinsman, 1993). Despite the lack of commercially harvestable densities of surfclams, juvenile forms of the surfclams have been recorded in increasing densities on the Hen and Chickens Shoal in recent years. This has been confirmed by the recent benthic sampling conducted by Dames and Moore in 1993 which revealed that 75% of the samples contained specimens of juvenile surfclams. The maximum size surfclam collected was approximately 1.5 cm. Minimum size limits for harvestable surfclams are set at 4.75 inches (approximately 120 mm), which is reached in 4-5 years (NOAA, letter dated 14 December 1995).

152. In addition to surf clams, the Delaware coastal area supports a small fishery for blue crabs *(Callinectes sapidus)*, which are harvested in the winter by dredging. The fishery is usually limited to a few licenses to avoid over-harvesting this stock, which consists mainly of female crabs that would be spawning the following spring and summer. The major portion of the blue crab population remains in Delaware Bay.

153. ***Freshwater Non-tidal Water Bodies.*** Three urbanized freshwater lakes are present within the vicinity of the project area. Lake Gerar in Rehoboth Beach receives drainage from nearby developments and is primarily surrounded by a thin buffer of maintained parkland and a relatively undeveloped woodlot on the west end. Silver Lake, between Rehoboth Beach and Dewey Beach, is the largest lake within the project area, and is surrounded by maintained lawns and residential development. Several stretches of emergent wetlands vegetated with common reed *(Phragmites australis)* are present along the shoreline. Silver Lake is notable for wintering waterfowl including Canada geese *(Branta canadensis)*, mallard *(Anas platyrhynchos)*, black duck *(Anas rubripes)* and canvasbacks *(Aythya vallisneria)*. Fishery resource values of Silver Lake are described as relatively low (USFWS, 1994). The western end of Silver Lake, until recently, was flanked by an undeveloped dune system. These dunes were breached by storm waves during the winter of 1993 introducing saline water into the lake.

154. Lake Comegys is also between Rehoboth Beach and Dewey Beach, however is much smaller than Silver Lake. This lake lies west of Silver Lake Drive, and also is flanked by heavy residential development.

155. ***Inland Bays.*** The Delaware coastal beaches are bordered on the west by three inland embayments: Rehoboth Bay, Indian River Bay, and Little Assawoman Bay. The inland bays are bordered extensively with tidal marshes composed of salt marsh cordgrass *(Spartina alterniflora)*, saltmeadow hay *(S. patens)*, spike grass *(Distichlis spicata)*, and high tide bush *(Iva frutescens)* (Daiber et al.,1976). Rehoboth Bay is the nearest inland embayment to the study area and borders the barrier island on the west at the town of Dewey Beach. High development is present along the back-barrier of Dewey Beach which was previously part of the tidal marsh complex that extends further south along Rehoboth Bay. Extensive tidal marshes are present along the western fringes of Rehoboth Bay. Rehoboth Bay has 48 miles of shoreline and a surface area of 14.8 square miles. Water depths at low tide are generally 7 feet or less. Saline water enters Rehoboth Bay from Indian River Bay and from the lower Delaware Bay through the Lewes-Rehoboth Canal. Due to differences in tidal marine and freshwater inputs, salinities vary throughout the bay on a daily, seasonal, and locational basis. Orris (1972) reported that salinities in Rehoboth Bay ranged from 20.1 to 30.6 ppt.

156. Common estuarine fishes present in the inland bays include: bay anchovy, Atlantic silverside, mummichog, striped killifish, naked goby, and hogchoker. The inland bays are important nurseries for a variety of commercial and recreational fishes including: spot, croaker, weakfish, menhaden, bluefish, and summer flounder. Rehoboth bay supports adequate numbers of hard clam *(Mercenaria mercenaria)* and blue crab *(Callinectes sapidus)* for recreational and/or commercial fisheries. The inland bays are also important for supporting a variety of waterfowl, shorebirds, and wading birds.

157. **Threatened and Endangered Species.** The only Federally or state listed endangered or threatened species known to occur near the project area on more than an occasional or transient basis is the piping plover *(Charadrius melodus)*. These small shorebirds, which are classified as endangered on both the Federal and State lists, nest on coastal beaches and dunes. Most of Delaware's Atlantic beach and dune system, except in high development areas is potential nesting habitat. In recent years, piping plover have been nesting at Cape Henlopen and Delaware Seashore State Parks. The nesting season usually begins in late March when the birds arrive and ends in July when the young are finally fledged. Shortly after hatching, the young leave the nest and begin foraging along the shoreline. The adults accompany the young during this critical period until they are fledged 25-35 days later. The State of Delaware has an active program to protect the bird's nesting activities. The program includes annual surveys to detect nesting birds and installation of fencing to close the nesting areas to intruders. The beaches and dunes within the confines of the Rehoboth/Dewey Beach study areas have not had any nesting sites for piping plovers.

158. Other avian threatened and endangered species may be present in only occasional and transient bases, which may include the bald eagle *(Haliaeetus leucocephalus)* and peregrine falcon *(Falco peregrinus* and *F. peregrinus tundrius)*.

159. The Delaware coast may be occasionally visited by five species of threatened and endangered sea turtles. These turtles include the loggerhead turtle *(Caretta caretta)*, green turtle *(Chelonia mydas)*, hawksbill turtle *(Eretmochelys imbricata)*, Kemp's ridley turtle *(Lepidochelys kempii)* and leatherback turtle *(Dermochelys coriacea)*. The loggerhead turtle and Kemp's ridley turtle are particularly more common in Delmarva coastal waters during summer months. Historically, the breeding range of the loggerhead turtle may have extended to the Delaware Atlantic Coast, however, there are no known nesting sites reported in this stretch of coast. The other four species breed much further south from Florida through the Caribbean and Gulf of Mexico. Overall, sea turtle utility of Delaware's twenty-five mile stretch of Atlantic Ocean presently or historically has not been significant. Sea turtles primarily utilize Delaware coastal waters as a transportation route from the Gulf Stream to Delaware Bay, where significant numbers have been observed utilizing the bay's resources as a nursery and feeding area (Logothetis, 1994).

160. The only endangered fish that may be in the study area is the shortnose sturgeon *(Acipenser brevirostrum)*. The shortnose sturgeon is an anadromous fish that primarily inhabits estuarine waters of the Delaware Bay and River. In the spring adults migrate from lower estuary and freshwater overwintering sites, upstream to upper tidal and lower non-tidal spawning grounds. In the fall, the bulk of the population migrates to the lower estuary to overwinter. The shortnose sturgeon is a benthic feeder and its diet is mainly composed of small worms and crustaceans.

161. Six species of endangered whales may occasionally be encountered in nearshore waters along the Delaware Atlantic Coast during their migrations. These include sperm whale *(Physeter ocatodon)*, fin whale *(Balaenoptera physalus)*, humpback whale *(Megaptera novaeangliae)*, blue whale *(Balaenoptera musculus)*, sei whale *(Balaenoptera borealis)* and black right whale *(Balaena*

glacialis).

162. Two rare plant species, sea beach pigweed *(Amaranthus pumilus)* and chaffseed *(Schwalbea americana)*, can be found in beach and dune habitats in Delaware. However, there are no records of these species occurring in the study area.

163. **Air Quality.** Through the State Implementation Program, air quality is managed by the Delaware Department of Natural Resources and Environmental Control. The goal of the State Implementation Plan is to meet and enforce the primary and secondary national ambient air quality standards for pollutants. Management concerns are focussed on any facility or combination of facilities which emit high concentrations of air pollutants into the atmosphere. Manufacturing facilities, military bases and installations, oil and gas rigs, oil and gas storage or transportation facilities, power plants, deep water ports, LNG facilities, geothermal facilities, highways, railroads, airports, ports, sewage treatment plants, and desalinization plants are facilities and activities that may cause air quality problems (NOAA & DECMP, 1980).

164. The State of Delaware Air Quality Management Section operates one air quality monitoring station in Sussex County at Seaford. Unlike the heavily populated and industrialized New Castle County, Sussex County is primarily rural without any significant sources contributing to air pollution. Overall, air quality in Sussex County is considered to be good, however, exceedences of air quality criteria for ozone designate Sussex County as "marginally" non-attainable in meeting air quality criteria for ozone. With the exception of ozone, all other air quality criteria are met in Sussex County (Personal communication with John Thomas-DNREC Air Quality Management Section).

165. This project was determined to be in compliance with the State Implementation Plan (SIP) based on coordination with the State and EPA Region III. A statement of conformity with the SIP is presented in page 9-1 of the EIS.

166. **Hazardous, Toxic, and Radioactive Wastes (HTRW).** A literature review was conducted within the study area to assess the potential of encountering any contamination associated with HTRW. This literature review utilized various databases from the non-Federal sponsor, DNREC, the United States Environmental Protection Agency (USEPA), PCB-Waste Handlers (PADS), Small and Large Quantity Hazardous Waste Generators, and Treatment, Storage and Disposal of Hazardous Waste Facilities (HWDMS/RCRIS), National Priorities List (NPL), Facility Index System (FINDS) List, Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS), Radioactive Materials (MLTS), Release of Toxic Chemicals to Air, Water, and Land (TRIS), Manufacture or Importer of Toxic Substances (TSCA), Emergency Response Notification System (ERNS), Hazardous Materials Incident Report System (HMIRS), DE State Hazardous Waste Sites (SHWS), Leaking Underground Storage Tank Incidents (LUST), Registered Underground Storage Tank (UST), and Solid Waste Facility/Landfills (SWF/LS), and State Hazardous Waste Sites (SHWS). No sites were identified from this database inventory search at or within three miles of the Delaware coastline.

167. The National Oceanic and Atmospheric Administration (NOAA) Cape Henlopen to Indian River Inlet Soundings Map indicates an area approximately three miles off the coast that has been designated a danger zone. Ocean-going vessels are permitted to navigate in this zone, however, all vessels are cautioned not to anchor, dredge, trawl, lay cable, or conduct any other activity that involves disturbing the substrate due to the potential danger from mines being buried within the substrate. The proposed sand borrow source is located outside of this area, and has been investigated by remote sensing magnetometer surveys during archaeological investigations. Two magnetic anomalies were recorded within the proposed borrow area. There will be further investigations if the anomalies cannot be avoided (Appendix A, Section 5).

168. Given the type of environmental settings within the study area and the associated land uses, the likelihood of encountering HTRW's is extremely low. No immediate concerns were identified from site visits, regulatory agency contacts, and database searches, therefore, any further HTRW investigations for the Rehoboth Beach/Dewey Beach study area are not necessary.

EXISTING CULTURAL RESOURCES

169. **Prehistoric Resources.** The prehistoric occupation of Delaware and the Delmarva Peninsula has been categorized by archaeologists into three general periods of cultural development: Paleo-Indian (15,000 years before present (B.P.) - 8,500 B.P.), Archaic (8,500 B.P. - 5,000 B.P.), and Woodland (5,000 B.P. - 400 B.P.). Few Paleo-Indian sites have been located in the Delaware region of the Delmarva Peninsula. This is partly due to the low population density and nomadic lifestyle of the people from the period, as well as from the inundation of sites by sea level rise and burial under thick layers of alluvium and modern cultural deposits. Archaic period sites tend to be relatively small, suggesting short-term and intermittent occupations. Archaeological investigations have traditionally focused on Woodland period sites. Many Early Woodland period base camps have been located along brackish rivers. By the Late Woodland period, there is evidence of a further sedentary lifestyle with an increasing reliance on agriculture. Woodland sites have been identified on both the coastal marshes and in the mid-drainage areas in the region. Two prehistoric archaeological sites in the Rehoboth Beach area, the Warrington Site (7S-G-14) and Thompsons Island Site (7S-G-4), are listed on the National Register of Historic Places. These sites will not be affected by the proposed project.

170. **Historic Resources.** The early history of the Delaware Coast was marked by a succession of 17th century European expeditions. In 1631, the Dutch established the small whaling community and settlement of "Zwaanendael" near Cape Henlopen. The first Swedish expedition sailed into the Delaware in 1638 and established the region's first permanent European settlement at Wilmington, Delaware. Two historic archaeological sites, the Avery Rest Site (7S-G-57) and Thompson's Loss and Gain Site (7S-G-60) and three historic properties, the Peter Marsh House, Dodd Homestead, and All Saints' Episcopal Church, in the Rehoboth Beach vicinity are listed on the National Register of Historic Places. These sites and properties will not be affected by the proposed project.

171. **Maritime Resources.** Although the Delaware Bay was documented in 1609 and explored

by others in 1616, the first comprehensive navigational chart of the Delaware Coast vicinity was not completed until 1756. Privately published charts were available in the first half of the nineteenth century. However, standardized coastal charts were not initiated until the first United States Coast Survey was completed in the mid-nineteenth century. In 1878, the United States Coast and Geodetic Survey began to periodically update the chart of the vicinity with detailed hydrographic information. The earliest known aid to navigation in Delaware was the Cape Henlopen Light which was erected in 1767. A second light was constructed on Fenwick Island in 1858. Two breakwaters creating a Harbor of Refuge were constructed inside Cape Henlopen between 1828 and 1901 to provide vessels protection from storms and ice at the mouth of the bay. By the middle of the nineteenth century the U.S. Coast Guard had established a series of lifesaving stations at Lewes, Cape Henlopen, Rehoboth Beach, Indian River Inlet, Bethany Beach and Fenwick Island. Historic maritime activity within the project areas was almost exclusively transient, with vessels crossing the area on coastal networks linking the Delaware ports and New York with other ports from Maine to Texas and the Caribbean to Central and South America.

172. Over the years, many types of ships and vessels have wrecked while en route up and down the coast. Many vessels were lost along the coast in an attempt to reach the Harbor of Refuge. Coastal storms, treacherous northeast winds and swift tidal currents coupled with historically heavy coastal traffic has caused the loss of dozens of documented sailing vessels, steamships, barges, tugs and large modern ships off the Delaware Coast. A variety of potential submerged cultural resource types in the project vicinity could date from the first half of the seventeenth century through the Second World War. The remote sensing survey of the borrow area identified two magnetic targets that exhibit shipwreck characteristics. In addition, remnants of a possible shipwreck or what could be the remains of a wood piling structural foundation are buried on the shoreline in front of the "Star of the Sea" building in Rehoboth Beach.

173. **Submerged Prehistoric Sites.** During the last glacial period, which terminated approximately 15,000 years ago, the sea level was 95 to 130 meters lower than current levels. The Delaware Atlantic shoreline at this time was on the edge of the modern continental shelf, some 50 to 60 kilometers east of the present shoreline. According to area studies, the sea level rose at a steady pace between 7000 B.P. and 3000 B.P., with a slower rate of increase after ca. 3000 B.P. There is a possibility that prehistoric pleistocene land surfaces are buried under shoaled offshore sand deposits at the borrow area.

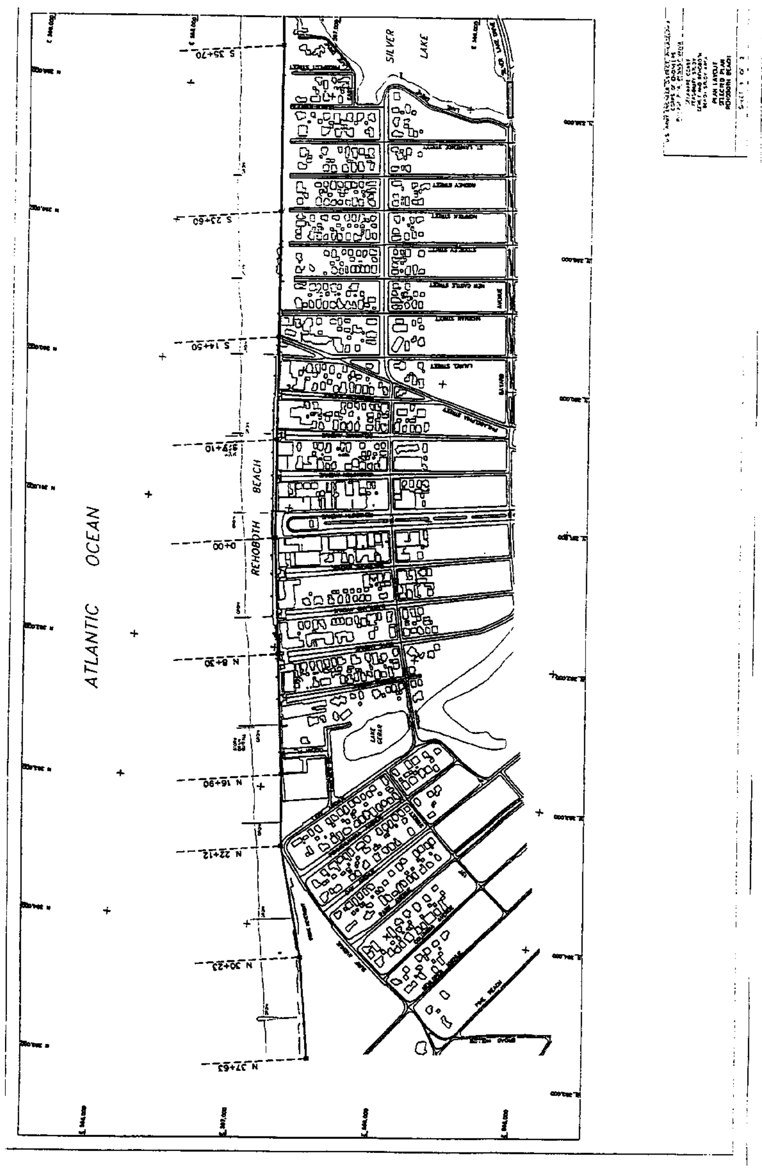
WITHOUT-PROJECT FUTURE CONDITIONS

174. **General.** In order to assess the "Without Project" conditions, the natural processes that affect the oceanfront were evaluated as they contribute to the Federal objective of hurricane and storm damage reduction. The objective of any plan of improvement was to reduce the damages caused by these processes. Storm erosion and inundation analyses were conducted for Rehoboth Beach and Dewey Beach to determine the potential for damages. Storm-induced erosion and coastal flooding were first evaluated for the without-project condition, which is a projection of conditions likely to occur by the base year. The economic impacts of the without-project scenario were then determined, providing the basis for comparing alternative shore protection features during plan formulation.

WITHOUT-PROJECT HYDRAULIC ANALYSIS

175. **Typical Profile Representation.** Profiles were chosen to represent the typical characteristics of existing conditions of the beach for the coastal processes analyses. The beach profile data was developed from survey data collected between 1982 and 1993 at Rehoboth Beach and Dewey Beach. Each profile in the project area is unique, including shore protection structures, and developed for the average conditions. Each profile was extended landward using 1993 digital photogrammetry elevations, to allow for erosion and inundation computations into the community. A design baseline was established, from which all measurements of profile recession and inundation delineation are referenced. Figure 12 shows the profile and baseline locations. Figure 13 represents an example of the profile utilized for the coastal processes analyses.

176. **Long Term Erosion Rates.** The long term erosion rates for the Rehoboth Beach and Dewey Beach were estimated based on the historic record of shoreline position and profile surveys. The historical information show a pattern of alternating accretion and erosion along the entire Delaware coastline. The observed erosion/accretion rates were averaged over varying shoreline lengths to normalize the effects of the fluctuations. Within the project area the rates of erosion ranged from almost 6 feet a year just south of Dewey Beach to virtually stable within the Rehoboth Beach groin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REHOBOTH BEACH
SILVER LAKE
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N 16+90
N 22+12
N 30+23
N 37+63

Figure 12

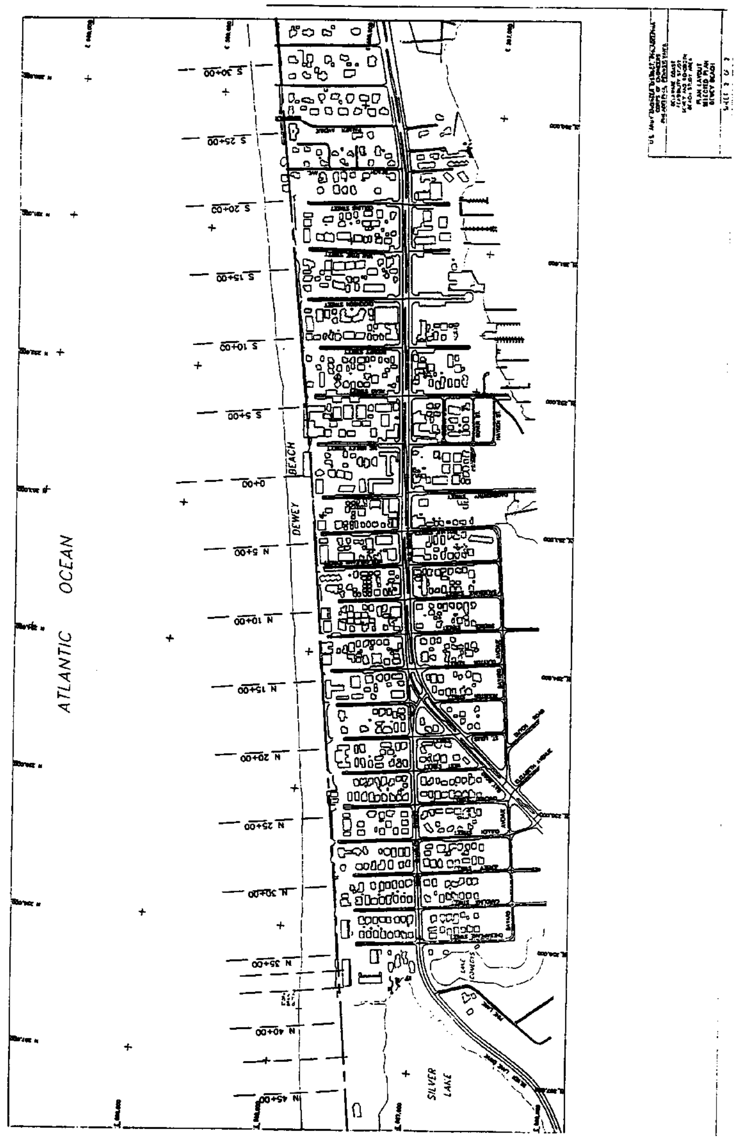
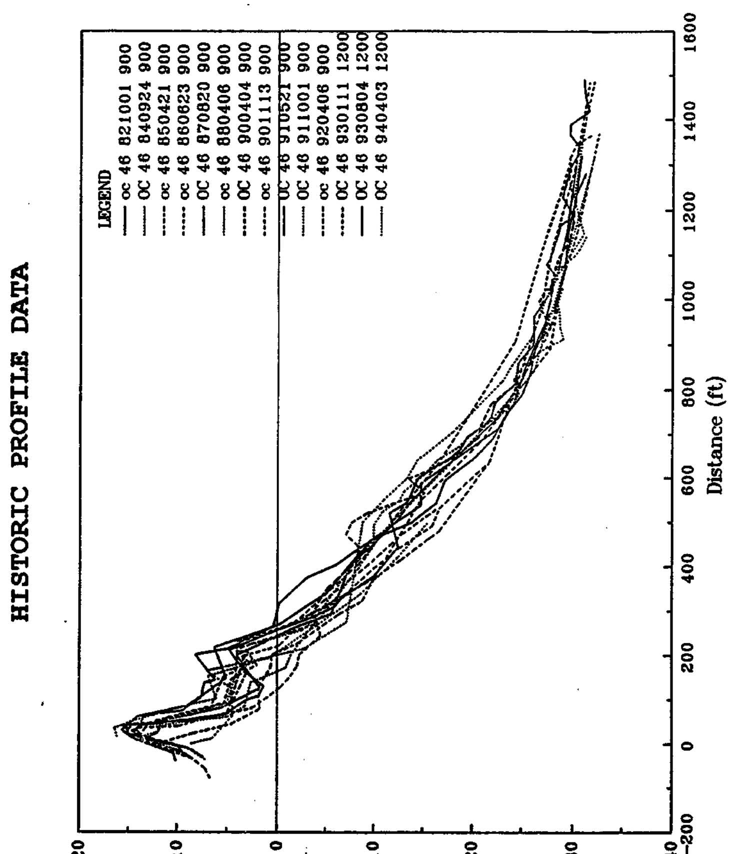


Figure 12 Continued


HISTORIC PROFILE DATA
LEGEND
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OC 46 930111 1200
OC 46 930804 1200
OC 46 940403 1200
Elevation (ft)
20
10
0
-10
-20
-30
-40
Distance (ft)
-200
0
200
400
600
800
1000
1200
1400
1600

Figure 13

field. Based on the analysis of the historic data it was determined that the study area would be characterized by two zones of shoreline change rates, north and south respectively. The estimated rate adopted for the northern area (Rehoboth Beach) was retreat of 1 ft/year. For the southern area (Dewey Beach) the adopted retreat rate was 4 ft/year, with a transition area (Silver Lake) between with estimated retreat of 2.5 ft/year. These rates were utilized in estimating the background long term volumetric erosion rates for the project area, and in establishing the base year estimate of starting conditions.

177. The without-project assumption includes the provision that the communities of Rehoboth Beach and Dewey Beach will not let the long term shoreline erosion encroach into their communities. The towns would "take action" to hold the line when erosion encroaches upon the bulkhead line in Dewey Beach and the seaward edge of the boardwalk in Rehoboth Beach. The average profile characteristics developed from the recent beach surveys are considered to be the existing condition profiles used in the without-project analyses.

178. **Storm Erosion and Inundation Analyses.** A brief summary of the mechanisms which result in beach erosion and inundation of communities from coastal storms is provided in this section. Although wind, storm track, central pressure, and precipitation are the primary meteorological factors affecting the damage potential of coastal storms, the major causes of damage and loss of life are storm surge, storm duration, and wave action.

179. Under storm conditions, there is typically a net increase in the ocean water level which is superimposed on the normal astronomic tide height fluctuations. The increase in water level caused by the storm is referred to as "storm surge." The effect of storm surge on the coast depends on the interaction between the normal astronomic tide and storm-produced water level rise. For example, if the time of normal high tide coincides with the maximum surge, the overall effect will be greater. If the surge occurs at low or falling tide, the impact will likely be lessened. The term "stage" as applied in this analysis pertains to the total water elevation, including both tide and storm surge components, relative to a reference datum (NGVD, used herein). The term "surge" is defined as the difference between the observed stage and the stage that is predicted to occur due to normal tidal forces, and is thus a good indicator of the magnitude of storm intensity. Slowly moving "northeasters" may continue to build a surge that lasts through several high tides. Such a condition occurred during the devastating March 1962 storm which lasted for five high tides. In addition to storm surge, a rise in water level in the near shore can occur due to wave setup. Although short period surface waves are responsible for minimal transport in the direction of wave propagation in open water, they may cause significant transport near shore upon breaking. Water propelled landward due to breaking waves occurs rather rapidly, but water returned seaward under the influence of gravity is slower. This difference in transport rates in the onshore and offshore directions results in a pileup of water near shore referred to as wave setup. Wave setup was computed and included in storm analysis.

180. There is typically also an increase in absolute wave height and wave steepness (the ratio of wave height to wave length). When these factors combine under storm conditions, the higher, steeper

waves and elevated ocean stage cause a seaward transport of material from the beach profile. The net movement of material is from the foreshore seaward toward the surf zone. This offshore transport creates a wider, flatter nearshore zone over which the incident waves break and dissipate energy. The beach profile evolves in this manner toward an equilibrium configuration with the storm conditions.

181. **Modeling Storm Induced Erosion.** Analyses of storm-related erosion for coastal sites require either a long period of record over which the important storm parameters as well as the resultant storm erosion are quantified, or a model which is capable of realistically simulating erosion effects of a particular set of storm parameters acting on a given beach configuration. There are very few locations for which the necessary period of prototype information is available to perform an empirical analysis of storm-induced erosion. This is primarily due to the difficulty of directly measuring many important beach geometry and storm parameters, before, during, and immediately after a storm. Thus, a systematic evaluation of erosion under a range of possible starting conditions requires that a numerical model approach be adopted for the study area.

182. The USACE has developed, adopted and released the numerical storm-erosion model SBEACH (Storm Induced BEAch CHange) for use by field offices. SBEACH is a geomorphic-based two-dimensional model which simulates beach profile change, including the formation and movement of major morphologic features such as longshore bars, troughs, and berms, under varying storm waves and water levels (Rosati, et al. 1993). SBEACH has significant capabilities that make it useful for quantitative and qualitative investigation of short-term, beach profile response to storms. Since SBEACH is based on cross-shore processes, caution should be used when using the model in the vicinity of inlets, structures, and areas with strong longshore gradient in transport processes.

183. Input parameters include varying water levels as produced by storm surge and tide, varying wave heights and periods, and an arbitrary grain size in the fine-to-medium sand range. The initial beach profile can be input as either an idealized dune and berm configuration or an arbitrary (surveyed) total profile configuration. SBEACH allows for variable cross-shore grid spacing, simulated water-level setup due to wind, includes advanced procedures for calculating the wave breaking index and breaker decay, and provides an estimation of dune overwash. Shoreward boundary conditions that may be specified include a vertical structure (that can fail due to either excessive scour or instability caused by wave action/water elevation) or a beach with a dune of arbitrary configuration.

184. **Development of Input Data.** For each profile, a transect was selected representing the "average" shoreline, structure, backshore configuration, and upland development conditions. Storm erosion and inundation were computed relative to the designated project baseline. The results presented later in this section are provided relative to the project baseline.

185. ***Profile Data.*** The present (i.e. project base year) condition in the shoreline cells were represented by the average conditions developed from beach profiles surveyed between 1991 and 1993 that were spaced irregularly through the project area. Figure 12 presents the locations of the

beach profiles. For economic analysis purposes the profiles were named with consecutive numbers starting at the southern end of the study area to the northern end in Rehoboth Beach. In areas where there are structures between surveyed profiles, composite profiles were created. Table 12a lists the relationship between analysis profile number and survey profile number. The locations of erosion control structures were input into the SBEACH model for each profile. Based upon the erosion control structure characteristics, failure criteria were delineated for each relevant profile. Erosion control structures were specified to fail due to three possible conditions: scour at the toe, sufficient damaging wave height, or extreme water level to cause structural failure. Table 12 presents the criteria used for determining failure of coastal structures located within the study area.

186. ***Waves and Water Levels.*** The water level is the most important or first-order forcing parameter controlling storm-induced beach profile change, normally exerting greater control over profile change during storms than either waves or wind. Water level consists of contributions from the tide, storm surge, wave- and wind-induced setup, and wave run-up; the latter three are computed within SBEACH. Input data in this case is tide and storm surge data. The combined time series of tide and surge is referred to as the "hydrograph of total water level." The shape of the hydrograph is characterized by its duration (time when erosive wave conditions and higher than normal water elevations occur) and by its peak elevation. Combined water level data for the study area was obtained from the Lewes, Delaware tide gage and the CERC hindcast hurricane stage frequency analysis described in Appendix A, Section 2.

187. An elevated water level accompanying storms allows waves to attack portions of the profile that are out of equilibrium with wave action because the area of the beach is not normally inundated. Wave height and period are combined in an empirical equation within SBEACH to determine if the beach will erode or accrete for a time step. When modeling beach erosion, a storm is not defined by the water level, wave height or period, alone, but by the combination of these parameters that produces offshore transport. For each of the storm events used for this analysis wave data were obtained from the WIS database and the hurricane hindcast performed by CERC.

188. ***Storm Parameters.*** The twenty highest ocean stages recorded to affect the Delaware coast were examined and modified to create representative 5, 10, 20, 50, 100, 200, and 500 year storm events to be used as SBEACH input. The ocean stages of the twenty recorded storms were plotted on a stage frequency curve using Weibull plotting positions, and the 5, 10, 20, 50, 100, 200, and 500 year storm ocean stages were interpolated from this curve. Associated wave heights and periods for the above storms were similarly interpolated. Seven storms were selected based upon their actual peak wave heights or water levels being as close as possible to the desired extreme values and were adjusted to more closely simulate conditions of the storm event. The modified storms were used at all profiles in the project area.

TABLE 12a ANALYSIS PROFILE DESIGNATION		
STUDY AREA	Analysis Profile No.	Survey Profile
DEWEY BEACH	1	S15+00
	2	S10+00
	3	S5+00
	4	00+00
	5	N5+00
	6	N10+00 (B)
	7	N10+00
	8	N15+00
	9	N20+00
	10	N20+00 (B)
	11	N25+00
	12	N30+00
	12A	N30+00 (B)
	13	N35+00
REHOBOTH BEACH	15	S35+70
	16	S35+70 / 23+60
	16A	S23+60
	17	S14+50
	18	S7+10
	18A	S7+10 (B)
	19	00+00
	20	N8+30
	21	N16+90
	22	N22+12
	23	N30+23

(B) = BULKHEAD ADDED WITHIN PROFILE

TABLE 12
COASTAL STRUCTURE LOCATIONS AND FAILURE CRITERIA AND Without-project FAILURE EVENTS
(all elevations in feet, NGVD)

PROFILE	STRUCTURE LOCATION	SCOUR DEPTH	WATER ELEVATION	WAVE HEIGHT (ft)	FAILURE EVENT
3	39	1.0	13.5	8.0	20
6	69	1.0	13.0	8.0	50
8	51	3.0	15.0	8.0	100
10	110	2.5	15.5	8.0	200
11	71	2.5	16.0	8.0	200
12A	56	3.5	19.0	8.0	200
13	55	3.5	16.0	8.0	100
18A	26	2.0	14.5	8.0	100
19	18	2.0	14.5	8.0	100
20	18	2.0	14.5	8.0	100
21	12	1.0	13.5	8.0	100
22	-6	0.0	15.0	10.0	100

Notes:
1. Location measured feet landward of survey baseline.
2. Cells not listed have no erosion control structures.
3. Scour depth and Water elevation in feet NGVD.

189. SBEACH was used in this study to simulate the evolution of beach profiles for seven extreme storm events. The seven storm events modeled at each profile by SBEACH had peak wave heights and water levels that correspond to the extreme storms determined statistically as described previously for the 5-, 10-, 20-, 50-, 100-, 200-, and 500-year events.

190. **Calibration.** Calibration refers to the procedure of reproducing with SBEACH the change in profile shape produced by a storm. Due to the empirical foundation of SBEACH and the natural variability that occurs along the beach during storms, the model should be calibrated using data from

beach profiles surveyed before and after storms at the project coast or a similar coast. The calibration procedure involves iterative adjustments of controlling simulation parameters until agreement is obtained between measured and simulated profiles.

191. The best profile data set for calibration for the Rehoboth Beach/Dewey Beach study area consisted of profile surveys taken just prior to and just after the December 1992 storm. Additionally, wave data from the December 1992 storm was available from the directional wave gage operating at Dewey Beach during the storm event. Utilizing the available stage information at Lewes the calibration of SBEACH was completed. Representative beach profiles demonstrating the performance of the model for calibration profiles are presented in Figures 14, 15, and 16. Profile 140 has a high dune with a fairly wide berm and backshore elevations of +10' NGVD or greater, this profile is similar to profiles in the northern half of Dewey Beach and the unstructured profiles within Rehoboth. Profile 230 is analogous to the profiles that make up the southern half of Dewey Beach, small dune, reduced berm width, and backshore elevations typically less then +10' NGVD. Profile 125 is typical of the bulkheaded profiles within the study area. The SBEACH computed profile response was able to achieve good agreement on all three general types of profiles that are found throughout the study area.

192. **Storm Erosion Simulations.** The SBEACH model was applied to predict storm-induced erosion for the without-project conditions for the study area. Model output includes a post-storm profile plot, and several report and post-processing files. Simulation results from each particular combination of profile geometry and storm characteristics yield predicted profile retreat at three selected elevation contours. In this analysis, profile retreat for any given storm event was measured landward from the project base line to the location of the top of the erosion scarp on the beach face. Figures 17, 18, 19, and 20 present the 100 year frequency storm erosion results for typical structured and unstructured cells within Rehoboth Beach and Dewey Beach. The figures show the input pre-storm and the resultant post-storm profile based on SBEACH predicted retreat due to the 100-year frequency storm event.

193. ***Analysis of Model Results.*** The beach profiles that represent the study area were subjected to the 7 events, resulting in a total of 175 SBEACH simulations. All profiles containing erosion control structures were simulated with the structures in place. They were analyzed according to the failure criteria presented in Table 12 . Results of the without-project storm erosion analysis are presented in Table 13. These values are used as input to the economic effort which ultimately computes storm damages associated with storm related erosion. Eroded profile configurations for each profile are presented in Appendix A, Section 2.

194. **Storm Inundation Evaluation.** The project area is subject to inundation from several sources including ocean waves overtopping the beach and/or protective structures as well as flooding from inland bay and canal sources. The inundation can be categorized as two separate phenomena: 1) Flooding due to super-elevation of the water surfaces surrounding the project area and 2) wave attack, the direct impact of waves and/or high energy runup on coastal structures. In order to quantify the effects from flooding and wave attack, all inundation events are based on the ocean stage

frequency as discussed in an earlier section. Because the wave-effect contribution to total water level at the shoreline can be significant, wave setup is estimated and added to the stage-frequency curve or determination of the static flooding impact. Higher water elevations associated with wave runup were also evaluated at all vertical structures and profile crest locations.

195. **Flooding.** The project area is subject to flooding from back bay and adjacent waterways as well as direct ocean inundation. Construction of the proposed beach erosion control features will not significantly reduce the flood depths caused by the elevated stage of the surrounding waters. This elevated stage flooding is referred to as static or stillwater. The effects due to wave setup are considered in the inundation-stage frequency curve for assessing the impacts to the project area from flooding. Table 14 presents the adopted total inundation stage-frequency data from Table 3, adjusted to include the estimated setup at selected recurrence intervals.

196. The estimated "Backbay and canal" flooding levels were presented previously in Table 4. The added stillwater flooding from overtopping of the coastal structures and dunes were incorporated into the wave attack analysis.

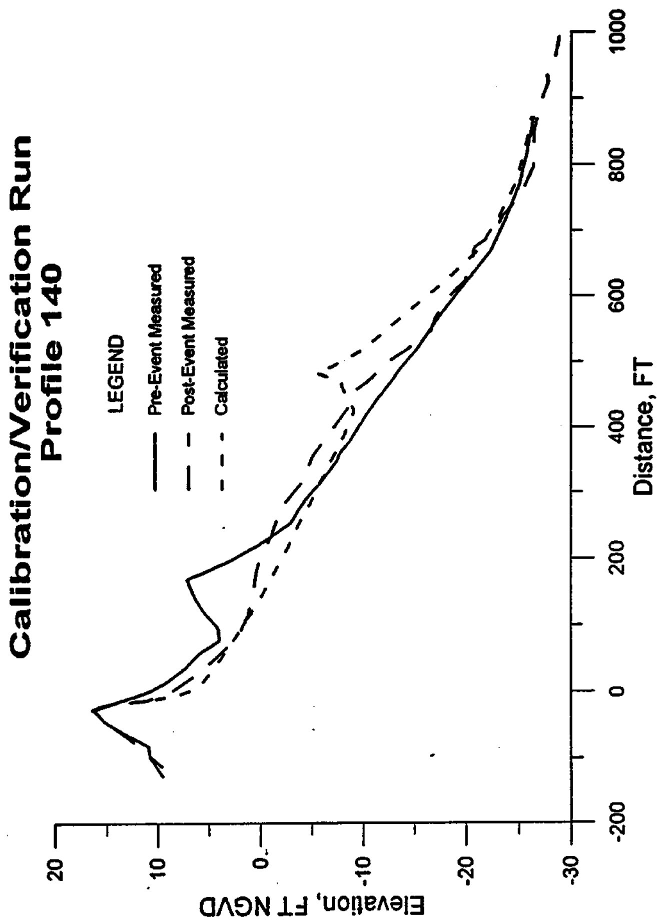
197. **Inland Wave Attack and Inundation Analysis.** The model SBEACH calculates nearshore wave characteristics, wave runup, wave setup and elevation of the beach profile for each hindcasted event. The wave runup and wave setup values are used, along with the eroded beach elevations, to determine inland water surface profiles, inland wave characteristics, and volumes of eroded material which in turn are used to assess economic damages landward of the project base line. Total water elevation profiles are constructed for each extreme event across the entire profile. The inland wave attack and inundation methodology used in this project is based upon FEMA guidelines for coastal flooding analysis. The procedure divides possible storm conditions into four cases briefly described below and in Appendix A, Section 2 as follows:

- Case 1: Entire storm-generated profile is inundated.

- Case 2: The top of the dune/profile crest is above the maximum water level, with wave runup greater than three feet above the dune crest elevation.

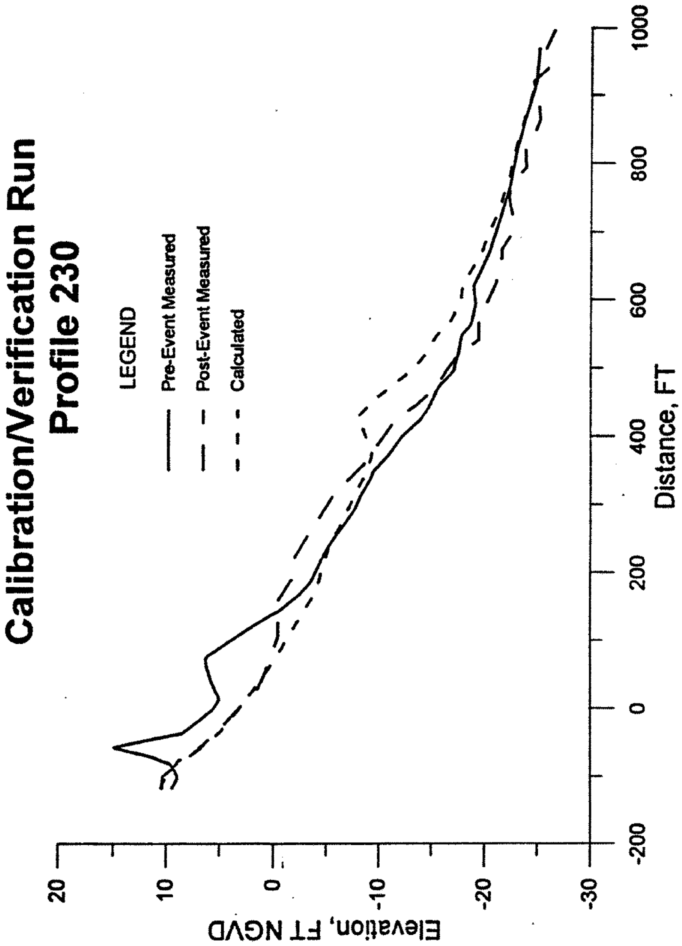
- Case 3: The top of the dune/profile crest is above the maximum water level, with wave runup exceeding but less than three feet above the dune crest elevation.

- Case 4: The wave runup does not overtop the dune. In this case, the wave zone is limited to seaward of the dune.



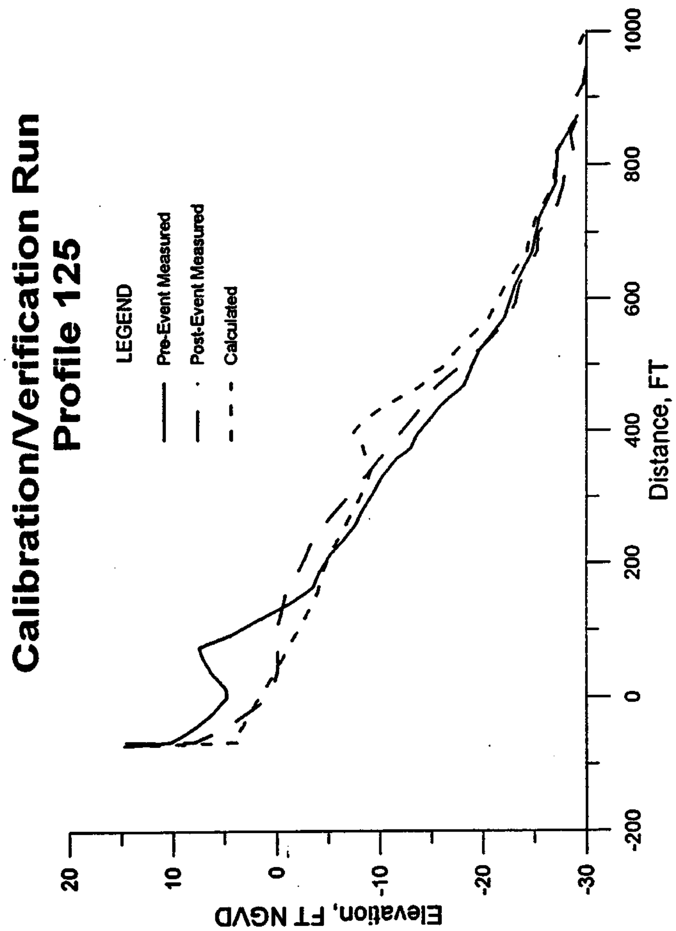
Calibration/Verification Run
Profile 140
LEGEND
Pre-Event Measured
Post-Event Measured
Calculated
Elevation, FT NGVD
20
10
0
-10
-20
-30
Distance, FT
-200
0
200
400
600
800
1000

Figure 14



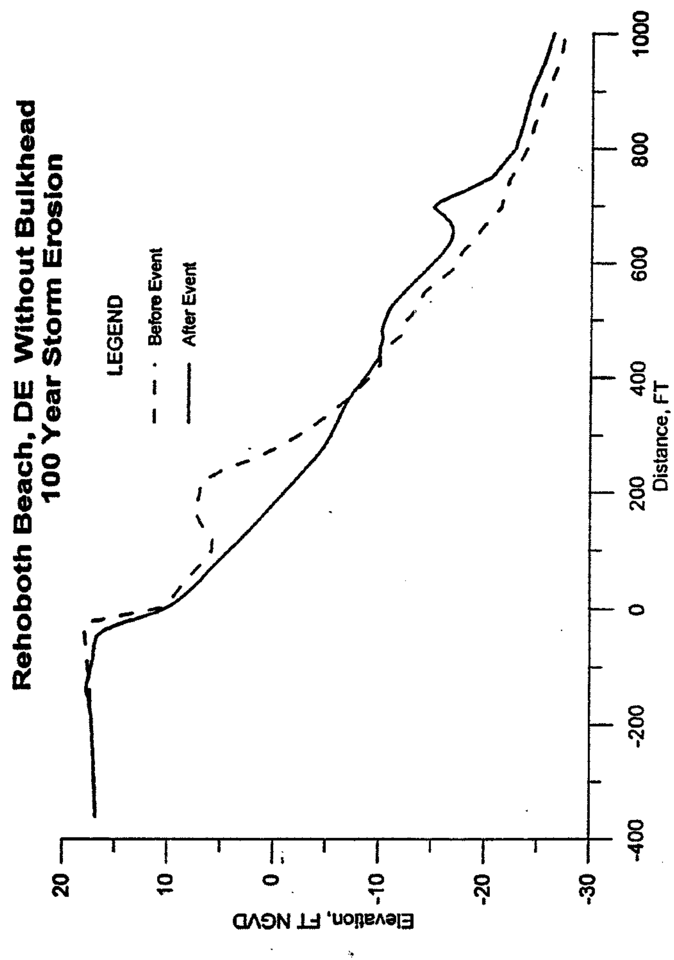
Calibration/Verification Run
Profile 230
LEGEND
Pre-Event Measured
Post-Event Measured
Calculated
Elevation, FT NGVD
Distance, FT
20
10
0
-10
-20
-30
-200
0
200
400
600
800
1000

Figure 15



Calibration/Verification Run
Profile 125
LEGEND
Pre-Event Measured
Post-Event Measured
Calculated
Elevation, FT NGVD
20
10
0
-10
-20
-30
-200
0
200
400
600
800
1000
Distance, FT

Figure 16



Rehoboth Beach, DE Without Bulkhead
100 Year Storm Erosion
LEGEND
Before Event
After Event
Elevation, FT NGVD
20
10
0
-10
-20
-30
Distance, FT
-400
-200
0
200
400
600
800
1000

Figure 17

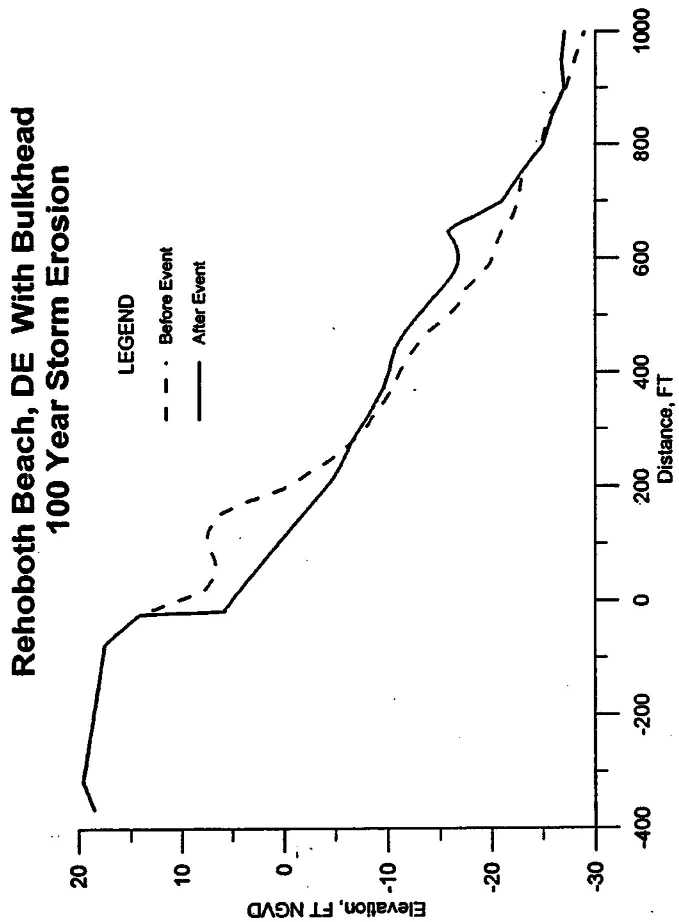

Rehoboth Beach, DE With Bulkhead
100 Year Storm Erosion
LEGEND
Before Event
After Event
Elevation, FT NGVD
20
10
0
-10
-20
-30
Distance, FT
-400
-200
0
200
400
600
800
1000

Figure 18

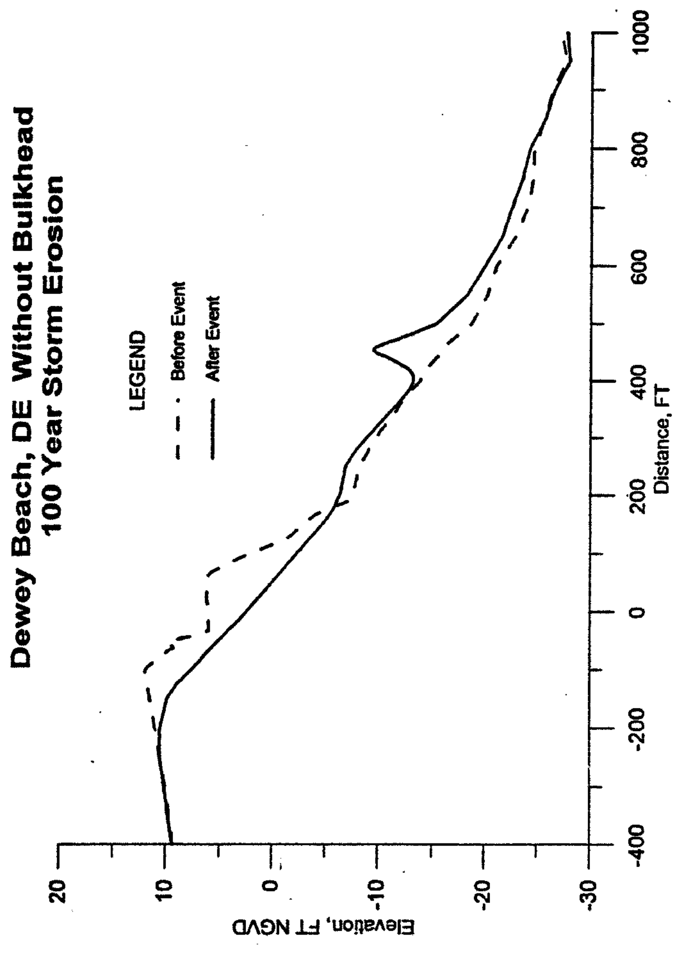
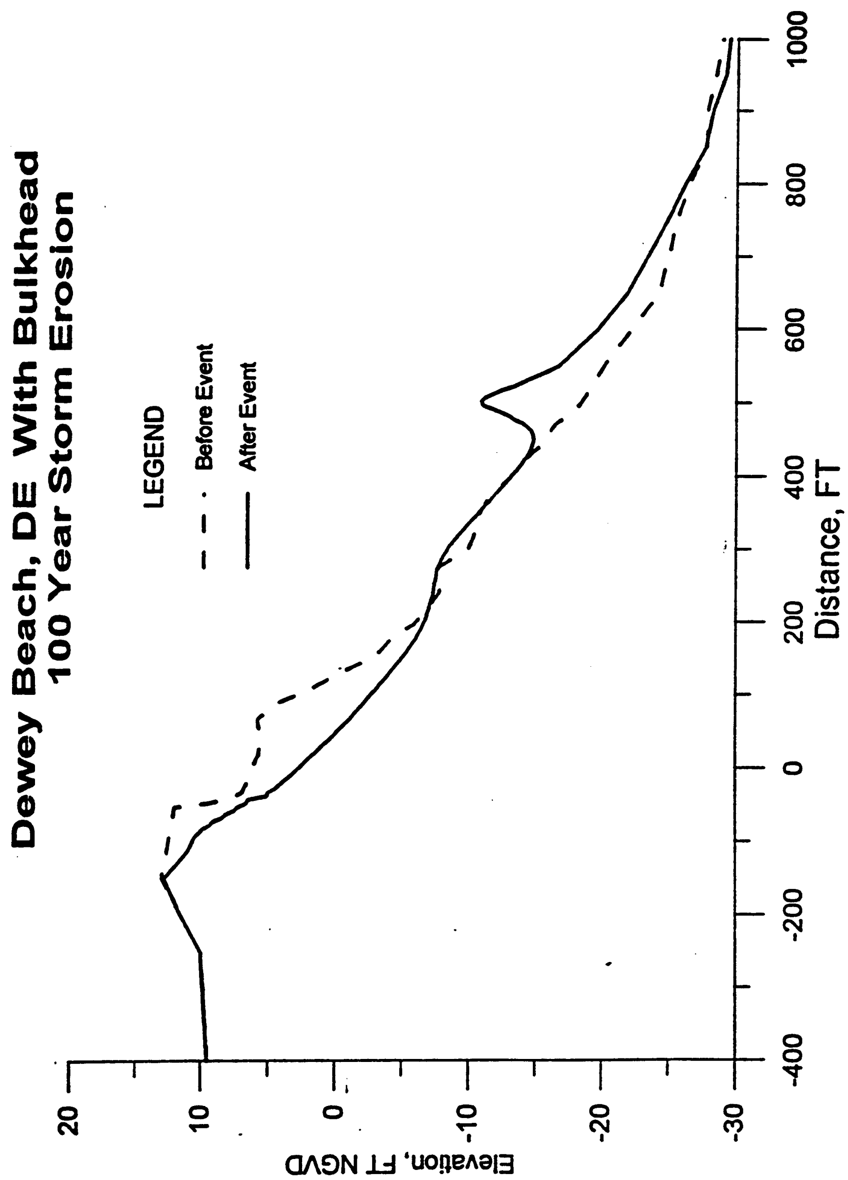

Dewey Beach, DE Without Bulkhead
100 Year Storm Erosion
LEGEND
Before Event
After Event
Elevation, FT NGVD
20
10
0
-10
-20
-30
-400
-200
0
200
400
600
800
1000
Distance, FT

Figure 19



Dewey Beach, DE With Bulkhead
100 Year Storm Erosion
LEGEND
Before Event
After Event
Elevation, FT NGVD
Distance, FT
20
10
0
-10
-20
-30
-400
-200
0
200
400
600
800
1000

Figure 20

TABLE 13
PREDICTED EROSION POSITIONS
FOR Without-project CONDITIONS
(feet landward measured from baseline)

PROFILE	5 YEAR	10 YEAR	20 YEAR	50 YEAR	100 YEAR	200 YEAR	500 YEAR
1	100	158	175	194	218	235	258
2	122	170	194	230	288	310	322
3	38	38	120	158	174	187	210
4	95	160	170	190	210	220	240
5	98	150	165	190	210	220	240
6	67	67	67	136	158	166	182
7	100	155	165	180	195	210	218
8	50	50	50	50	138	160	250
9	55	120	130	150	180	200	210
10	56	90	100	110	110	162	180
11	70	70	70	70	70	130	175
12	50	90	100	105	128	135	142
12A	50	50	50	50	60	70	125
13	55	55	55	55	78	125	190
15	-39	-37	-23	21	42	56	66
16	-32	8	16	28	54	66	77
16A	-28	-14	1	25	52	130	142
17	-6	8	13	45	129	147	160
18	-19	29	29	30	95	115	151
18A	25	25	25	26	189	204	218
19	16	16	16	18	180	220	237
20	17	17	17	18	81	171	210
21	12	12	12	12	47	142	152
22	-7	-7	-7	-2	92	174	224
23	11	22	50	153	178	198	228

TABLE 14 INUNDATION FREQUENCY STAGE PLUS WAVE SETUP	
ANNUAL EXCEEDENCE PROBABILITY	WATER SURFACE ELEVATION (Ft NGVD)
0.20	8.1
0.10	8.7
0.05	9.4
0.02	10.9
0.01	12.4
0.005	13.5
0.002	15.0

198. ***Criteria for Damage.*** To evaluate the added potential for structural damage, the boundaries of the wave attack must be delineated, and the critical damage wave height identified. Return periods of 5, 10, 20, 50, 100, 200, and 500 years associated with the inundation-frequency curve were evaluated for each profile. The analysis estimates the location of a wave attack line and the associated zones of high energy stages across the profile. The wave attack line is the most landward position of the swash zone where the force due to waves exceeds the force required to damage typical coastal structures. Any structure located landward of this line is subject to the equivalent of stillwater flooding because the wave heights are not sufficient to cause the accelerated damages incurred seaward of the line. A 3.0-ft wave height is assumed as the minimum wave that would cause damage to typical structures. This is based on the Corps of Engineers report "Guidelines for Identifying Coastal High Hazard Zones", and the FEMA's report "Guidelines and Specifications for Wave Elevation Determination and V-Zone Mapping", which both report a 3.0-ft wave height as the critical wave for damage.

199. The bulkheads, revetments, and seawalls located in the project area reduce the direct impact from wave attack and erosion damage. For all but the most extreme events, failure of the protective structures is required for significant wave attack to occur. However, extreme waves on certain profiles can plunge over the fixed barriers and attack the adjacent structures causing significant damage. The recurrence intervals in which the protective structures will fail for each profile were determined previously in conjunction with the erosion analysis, and are presented in Table 12.

200. ***Without-project Inundation Results.*** The effects of stage plus setup, wave amplitude, wave runup at structures or crest location were incorporated into the total water level. The total water level is the combination of the computed stage, the setup, the amplitude of the maximum non-breaking wave that can exist within the region, and/or runup height above the estimated water level

if waves are breaking on the beach face. The wave zones are the regions in which at least a 3 foot wave or a velocity flow that overtops the profile crest by 3 feet or greater can be expected to exist. These zones are the areas in which larger structural damages are expected to occur. The other zones are areas that are susceptible to flooding by overtopping and waves less than the 3 foot damaging wave. The total water level information for each profile in the study area was compiled, and the values used as input to the economic model which ultimately computes damages associated with storm related inundation. Table 15 lists the 5 through 500 year event 3 foot damaging Wave/runup impact zone measured in feet landward of the baseline. As an example, Table 16 presents the total water elevation profile which includes wave/runup attack for profile 7. Similar inundation profiles were computed for each profile to determine the total water level across the beach profile and into the community. The inundation results are presented in the "control" file format which is compatible for use with the Economics model COSTDAM.

201. The total water level includes stage, setup and runup or wave crest elevation, it is the maximum water elevation across the profile. The water level is listed in feet NGVD at several locations along the profile measured in feet landward of the baseline. The seven pairs of rows are read from top to bottom, 5 through 500 year event. The columns alternate distance landward of baseline and water elevation. Therefore, for the above example, the 100 year event water level at 0 feet landward of the baseline is +16 ft NGVD, then reading across at 245 feet the elevation is +14 ft NGVD, the next value is the first entry on the line below, 300 feet landward an elevation of +13 ft NGVD. It follows across to 1000 feet landward of the baseline the water level is +8 ft NGVD.

WITHOUT-PROJECT ECONOMIC ANALYSIS

202. **Structure Inventory and Replacement Costs.** A database of approximately 500 structures in the ocean block of Rehoboth Beach and 500 in the ocean block of Dewey Beach was compiled containing information described in the following paragraphs. Each structure was specifically inventoried and mapped on aerial photography at a scale of 1" = 50'. Information collected includes address, construction and quality type, and number of stories. First floor elevations, ground elevations, and type of foundations were obtained in cooperation with DNREC as an in-kind service. For multi-family residential and commercial structures the number of units and names of businesses were also gathered. The assimilation of this data was enhanced by using aerial ortho-digital mapping and the geographic information system, MIPS (Micro Imaging Processing System). Also included was information concerning tax data, such as square footage, number of bathrooms, type of heating systems, and the presence of basements, fireplaces, garages, and central air conditioning along with the structure's age. This information, along with quality and condition was entered into the Marshall and Swift Residential and Commercial Software Estimators which calculates depreciated replacement cost value. Only the replacement cost value for the first two floors (vulnerable to storm damage) of high rise buildings located in Rehoboth Beach was entered into the database and used to estimate damages.

TABLE 15
PREDICTED WAVE IMPACT ZONE POSITIONS
FOR Without-project CONDITIONS
(feet landward measured from baseline)

PROFILE	5 YEAR	10 YEAR	20 YEAR	50 YEAR	100 YEAR	200 YEAR	500 YEAR
1	100	158	175	219	270	330	410
2	122	170	194	280	390	425	307
3	38	38	145	208	239	335	350
4	95	160	195	240	280	370	415
5	98	150	165	240	270	330	400
6	67	67	67	186	225	266	307
7	100	155	165	230	297	325	400
8	50	50	50	75	168	210	300
9	55	120	130	150	205	250	310
10	56	90	100	110	150	212	282
11	70	70	70	70	70	155	225
12	50	90	100	105	128	155	192
12A	50	50	50	50	60	90	175
13	55	55	55	55	105	175	240
15	-39	-37	-23	21	42	56	66
16	-32	8	16	28	54	66	77
16A	-28	-14	1	25	52	130	142
17	-6	8	13	45	129	147	160
18	-19	29	29	30	95	115	151
18A	25	25	25	26	189	204	218
19	16	16	16	18	180	220	237
20	17	17	17	18	81	171	210
21	12	12	12	12	47	142	152
22	-7	-7	-7	-2	92	174	224
23	11	22	50	153	178	198	228

TABLE 16
INUNDATION ANALYSIS RESULTS - PROFILE 7
INUNDATION PROFILE: DISTANCE FROM BASELINE (Feet), TOTAL WATER SURFACE ELEVATION (Feet above NGVD)

	DIST	ELEV	DIST	ELEV	DIST	ELEV	DIST	ELEV
5 YEAR	0	12.0	100	12.0	150	8.7	200	6.4
	250	6.4	300	5.0	500	4.5	1000	4.0
10 YEAR	0	13.0	155	13.0	205	11.0	255	9.0
	305	7.0	355	7.0	405	5.0	1000	4.5
20 YEAR	0	14.0	165	14.0	215	13.0	265	11.0
	315	10.0	365	8.0	415	5.0	1000	5.0
50 YEAR	0	15.0	180	15.0	230	14.0	280	13.0
	330	11.0	380	9.0	500	6.0	1000	6.0
100 YEAR	0	16.0	195	16.0	210	15.0	245	14.0
	300	13.0	355	10.0	455	8.0	1000	8.0
200 YEAR	0	18.0	210	17.0	225	16.0	275	15.0
	325	13.0	375	11.0	425	10.0	1000	10.0
500 YEAR	0	18.0	220	18.0	250	18.0	300	16.0
	325	15.0	375	13.0	450	12.0	1000	11.0

203. The associated content value of each structure was assumed to be 25% of the structural replacement cost. This was based on personal interviews and walk through tours of homes. The ratio of contents to structural value ranged from a low of 15% for a typical townhouse secondary/vacation homes to a high of 150% for the homes of permanent residents. Twenty-five percent reflects the ratio of vacation homes to permanent homes in the communities.

204. **Storm Damage Methodology.** Damages were calculated for seven frequency storm events (5, 10, 20, 50, 100, 200, and 500 year events) for erosion, wave and inundation damage to structures, infrastructure and improved property. The calculations were performed using COSTDAM, which is a Fortran program originally written by the Wilmington District and updated for the Philadelphia District. COSTDAM reads an ASCII 'Control' file which contains the storm frequency parameters for each cell and an ASCII 'Structure' file which contains the database information of each structure as previously described. The program checks whether a structure has been damaged by wave attack, based on the relationship between a structure's first floor elevation and the total water elevation that sustains a 3 foot wave, erosion, and finally, inundation, for which damages occur if the water

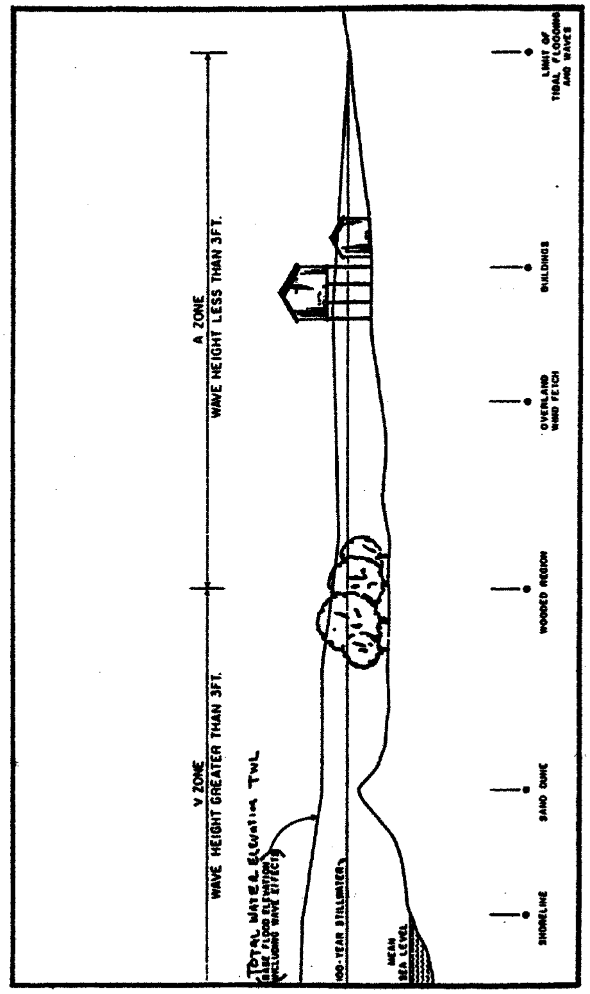
elevation is higher than the first floor elevation based on FIA depth-damage curves adjusted for increased salt water damagibility. To avoid double counting, if damage occurs by more than one mechanism, the program takes the maximum damage of any given mechanism (wave, erosion, inundation) and drops the rest of the damages from the structure's total damages (Figures 21 and 22). Average annual damages are then calculated. The damage categories as well as back bay residual damages and emergency/clean-up costs are described below and in Table 17.

205. **Improved Property Damages.** In addition to erosion damage to structures, damage to the land the structures are on (henceforth called improved property) is calculated. The improved property value is determined by comparing market value of the improved property (near shore land) to the cost of filling in the eroded improved property for reutilization and using the least expensive of the two values. The cost of filling/restoring the improved property is based on a typical 100'x50' lot for the linear feet and cubic yards of erosion produced by storms. The two options were compared for costs. The cost of filling/restoring the improved property is the less costly of the two options and was estimated to be an average of only 68% of the near shore land market value. The cost of fill is prorated to estimate total damages. Annual damages, at November 1993 price levels, in the without-project condition for improved property are $105,000 for Rehoboth Beach and $244,000 for Dewey Beach. Total improved property damages for both communities are $349,000, at November 1993 price levels.

206. **Infrastructure Damages.** Erosion damages for infrastructure are also calculated. Costs to replace bulkheads are estimated to be $900/linear foot. The replacement cost of roads is not a fixed value and decreased with greater quantities eroded reflecting economies of scale. The annualized without-project damages, at November 1993 price levels, for infrastructure (roads, utilities, bulkhead) including boardwalk are $276,000 for Rehoboth Beach and $94,000 for Dewey Beach. Total damages to infrastructure for both communities are $370,000 , at November 1993 price levels.

207. **Structure Damages.** The three damage mechanisms analyzed in this study are erosion, wave and inundation. Due to the fact that wave and inundation damages are related they are lumped into one category called wave/inundation. The following sections, in addition to summarizing the amounts of damages in each category, describe the methodology used to derive the amount of damages for each mechanism.

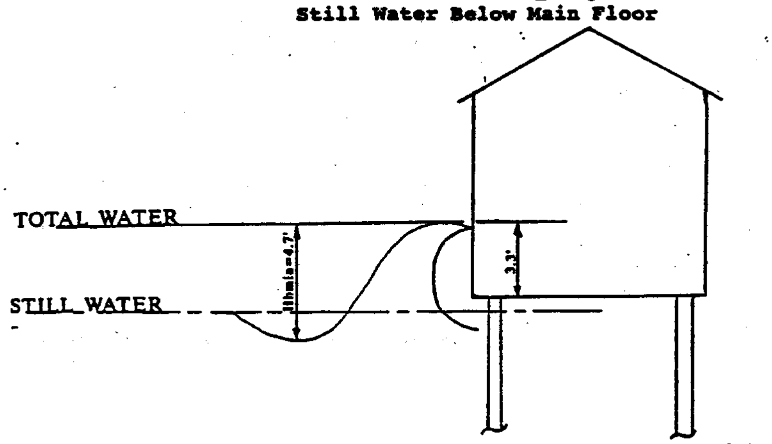
208. ***Erosion Damages.*** The distance between the reference (profile) line and the oceanfront and back walls are measured in AutoCAD using the georeferenced MIPS mapping of the study area. If the structure is not on a pile foundation, it is assumed that a structure is destroyed at the point that the land below the structure is eroded halfway through the structure. If the structure is on piles, erosion must retreat entirely through the footprint before total damage is claimed. Before total failure for both foundation types, the percent damage claimed is equal to the proportion of erosion under the structure's footprint relative to the total damage point, which is sometimes one half the footprint.



Typical Transect Schematic.

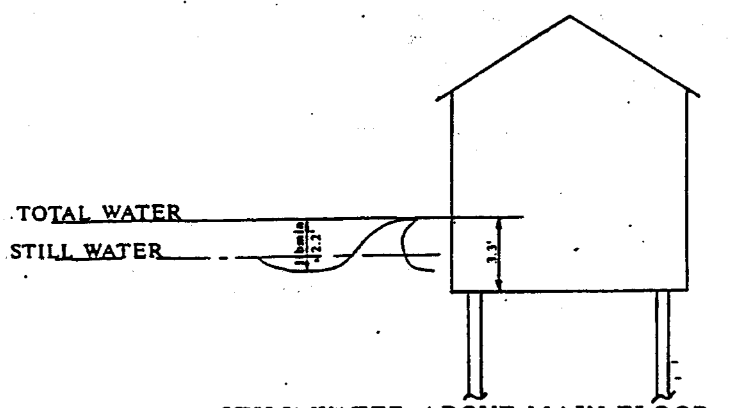
Figure 21

Two Wave Conditions Analyzed
for Grade Elevations ≥ Eight Feet
Still Water Below Main Floor



STILL WATER BELOW MAIN FLOOR

(Not To Scale)



STILL WATER ABOVE MAIN FLOOR

Figure 22

TABLE 17 ANNUALIZED DAMAGES BY CATEGORY AND EMERGENCY/CLEAN-UP COSTS November 1993 price level in 000's			
DAMAGES			
	REHOBOTH BEACH	DEWEY BEACH	TOTAL
IMPROVED PROPERTY	105	244	349
INFRASTRUCTURE	276	94	370
STRUCTURE:			
EROSION	275	1,422	1,697
WAVE/INUNDATION	239	748	987
TOTAL DAMAGES	895	2,508	3,403
COSTS			
	REHOBOTH BEACH	DEWEY BEACH	TOTAL
EMERGENCY/CLEAN-UP COSTS	48	53	101

For townhouse structures perpendicular to the ocean, each unit has its own unique ocean and back wall distances due to the local building ordinance which mandates that every unit have two hour fire walls. These walls should provide enough stability that townhouse units in a building can remain standing and be utilized after the unit(s) closer to the ocean is/are damaged. This has no bearing on townhouse units parallel to the ocean which would all have the same erosion point, because they are essentially equal distance from the reference line. Other multi-family structures such as apartments and condominiums will not have unique erosion points for each unit, because most of these structures were built before the local ordinance mandating fire walls was in place. Total annualized erosion damages, at November 1993 price levels, for Rehoboth Beach are $275,000 and for Dewey Beach are $1,422,000. Total erosion damages for both communities are $1,697,000, at November 1993 price levels.

209. ***Wave/Inundation Damages.*** A structure is considered to be damaged by a wave when there is sufficient force in the total water elevation to destroy a structure. Partial wave damages are not calculated; instead the structure is subjected to inundation damages. Large masonry structures like high rise condominiums do experience failure by wave damage. Because of the dominance of such structures along the oceanfront in Rehoboth Beach no wave damages are present. On the contrary,

Dewey Beach is largely composed of typical wood frame single family beach houses along the oceanfront that do experience wave damage.

210. The percentages of total replacement cost used to calculate damages by the depth-damage function curves for inundation damages reflect various characteristics of a structure. The depth-damage curves estimate the percent damaged at various depths relative to the first floor. Examples of the depth-damage curves are presented in Appendix B. These depth-damage curves used to estimate the damage to structures, are derived from previous studies of saltwater areas and FIA (Federal Insurance Administration) curves. The distinguishing characteristics are construction type (frame, concrete block, or masonry) and the number of stories in a structure. Total annualized wave/inundation damages, at November 1993 price levels, for Rehoboth Beach are $239,000 and for Dewey Beach are $748,000. Total wave/inundation damages for both communities are $987,000, at November 1993 price levels.

211. ***Total Damages to Structures.*** Annual damages to structures for Rehoboth Beach are $514,000, at November 1993 price levels and $436,000 indexed to October 1994 price levels and for Dewey Beach are $2,170,000, at November 1993 price levels and $2,238,000 indexed to October 1994 price levels. Structure damage in the entire study area total $2,684,000, at November 1993 price levels.

212. **Total Annual Damages.** Total annual damages for improved property, infrastructure and structures, at November 1993 price levels, is $973,000 for Rehoboth Beach and $2,508,000 for Dewey Beach. Total damages for both communities are $3,481,000, at November 1993 price levels.

213. **Back Bay Residual Damages.** COSTDAM is also run for the stages associated with the back bay (still-water) inundation. The results represent inundation damages that will not be eliminated by a project on the oceanfront. These back bay induced residual damages total, at November 1993 price levels, an annualized $71,000. This avoids overestimating benefits in the with-project condition for those cases where damages are reduced or eliminated for structures once eroded or damaged by wave but may still incur some damages due to inundation from the back bay. Rehoboth Beach does not experience this because uplands are behind the ocean block.

214. **Emergency/Clean-Up Costs.** Clean-up costs for individual structures are based on the time for clean-up and additional meal and travel costs. Travel and meal costs are included as opposed to evacuation costs because the vast majority of residential structures and even many commercial structures are occupied only on a seasonal basis, and even then, not always by the structure's owner. Clean-up costs are only applied to those structures affected by a particular storm event.

215. Emergency and clean-up costs are also calculated for public entities. This includes local, county and state governments and non-profit emergency service organizations. The costs are based on Federal Emergency Management Agency (FEMA) Damage Survey Reports for the January and December 1992 storms, which had stage frequencies of approximately 5 and 15 year events. Because of the lack of historical information, emergency and clean-up costs for larger events are extrapolated. The annualized emergency/clean-up costs, at November 1993 price levels, are $3,000 for individuals and $45,000 for public utilities in Rehoboth Beach and $9,000 for individuals and $44,000 for public utilities in Dewey Beach. Total emergency/clean-up costs for both communities are $101,000.

PLAN FORMULATION

PLANNING NEEDS, OBJECTIVES AND CONSTRAINTS

216. The purposes of this section are to provide background on the criteria used in the formulation process and to present the procedures followed from the identification of the study objectives to the identification of the selected plan. The results of these efforts are discussed in the succeeding sections. The formulation process involved establishment of plan formulation rationale, identification and screening of shore protection measures, and assessment and evaluation of detailed plans which are responsive to the identified problems and needs.

217. **Current Needs.** Over the years erosion has seriously reduced the ability of the shoreline in the study area to provide adequate storm damage protection for the towns of Rehoboth Beach and Dewey Beach. Continuation of this historic trend will increase the potential for economic losses and the threat to human life and safety.

218. The purpose of the feasibility study is to evaluate and, if warranted, recommend an implementable plan which provides protection to the towns of Rehoboth Beach and Dewey Beach against storm damage. This report considers various alternative solutions to reducing storm damage within the project area.

219. **Planning Objectives.** Planning objectives were identified based on problems, needs and opportunities as well as existing physical and environmental conditions present in the project area.

220. In general, the prime Federal objective is to contribute to the National Economic Development (NED) account consistent with protecting the Nation's environment. The pursuit and attainment of this objective must be consistent with national legal statutes, applicable executive orders, and other Federal planning requirements. The general and specific planning objectives for the Rehoboth Beach/Dewey Beach Interim Feasibility Study take an integrated systematic approach to the solution of the erosion and inundation problems associated with coastal storms and long term erosion in the towns of Rehoboth Beach and Dewey Beach. Accordingly, the following general and specific objectives have been identified.

General:

- Meet the specified needs and concerns of the general public.
- Respond to expressed public desires and preferences.
- Be flexible to accommodate changing economic, social and environmental patterns and changing technologies.
- Integrate with, and be complementary to, other related programs in the study area.

- Be implementable with respect to financial and institutional capabilities and public support.

Specific:

- Reduce the threat of potential future damages due to the effects of storms, with an emphasis on inundation and recession of the shoreline.

- Mitigate the effect of, or prevent, the long-term erosion that is expected to continue.

- In accordance with the limits of institutional participation, all plan components must maximize NED benefits.

- Where possible, preserve and maintain the environmental character of the areas under study, including such considerations as aesthetic, environmental and social concerns, as directly related to plans formulated for implementation by the Corps.

221. **Planning Constraints.** Planning constraints are technical, environmental, economic, regional, social and institutional considerations that act to reduce the theater of possible solutions. The following are established as planning constraints for the study:

Technical Constraints:

- Plans must represent sound, safe, acceptable engineering solutions.

- Plans must comply with Corps regulations.

- Plans must be realistic and reflect state-of-the-art measures and analysis techniques. They must not rely on future research and development of key components.

- Plans which consider elimination of a segment of the project area must ensure that the elimination of such areas do not adversely affect the protected areas or the areas which have been eliminated.

- Federal participation in the cost of restoration of beaches shall be limited so that the proposed beach will not extend seaward of the historical shoreline of record.

- The design of protective structures should, as a minimum, demonstrate that they will satisfactorily perform for design events up to and including the annual frequency which has a 50 percent probability of being exceeded during the economic life of the feature which is 50 years (See Engineering Technical Notebook).

Economic Constraints:

- Plans must be efficient. They must represent optimal use of resources in an overall sense. Accomplishment of one economic purpose cannot unreasonably impact another economic system.

- The economic justification of the proposed project must be determined by comparing the average annual tangible economic benefits which would be realized over the project life with the average annual costs. The average annual benefits must equal or exceed the annual costs.

- Federal participation in storm damage reduction projects requires that the project be economically justified primarily on benefits associated with storm damage reduction. Federal funds are not used to support storm damage reduction projects for which incidental recreation benefits are greater than 50 percent of the total benefits unless the project is economically justified on primary benefits alone.

Environmental Constraints:

- Plans cannot have an unreasonably negative impact on environmental resources.

- Where a potential impact is established plans must consider mitigation or replacement and should adopt such measures, if justified.

- NEPA documentation must be fully coordinated.

- Water quality standards must be maintained during construction activities in accordance with water quality certification requirements.

- Plans should avoid the destruction or disruption of man made and natural resources, aesthetic and cultural values, community cohesion, and the availability of public facilities and services;

Regional and Social:

- The needs of other regions must be considered, and one area cannot be favored to the unacceptable detriment of another.

- Consideration should be given to public health, safety, and social well-being, including possible loss of life.

- Plans should minimize the displacement of people, businesses and livelihoods of residents in the project area.

- Plans should minimize the disruption of normal and anticipated community and regional growth.

Institutional:

- Plans must be consistent with existing Federal, State and local laws.
- Public access plans must be obtained for those areas where sand is proposed to be placed creating new beaches, unless such placement is purely incidental to project function or for cost savings to the Government.
- Plans must be locally supported to the extent that local interests must, in the form of a signed Project Cooperation Agreement (PCA), guarantee items of local cooperation including cost sharing.
- Local interests must agree to provide public access to the beach in accordance with all requirements of State laws and regulations.

PLAN FORMULATION

222. This section describes the formulation procedure and results for the Rehoboth Beach/Dewey Beach Interim Feasibility Study. The purpose of formulation is to identify plans which are publicly acceptable, implementable, and feasible from economic, environmental, engineering and social standpoints.

223. ER 1105-2-100 requires the systematic preparation and evaluation of alternative solutions for addressing identified problems, needs and opportunities under the objective of National Economic Development (NED) consistent with protecting the Nation's environment.

224. The formulation was undertaken in three phases, or cycles: Cycle 1- Initial Screening of Solutions Considered, Cycle 2- In Depth Evaluation and Screening of Solutions Considered and Cycle 3- Optimization of the Selected Alternative Solution. By analyzing the alternative solutions in this manner one can formulate the solution that best fits the planning objectives and constraints in a logical and efficient fashion.

225. **Damage Mechanisms.** Alternative solutions considered include those which provide storm damage protection from a number of possible damage mechanisms:

(1) long term erosion
(2) storm recession
(3) inundation
(4) wave attack

226. Recreation benefits achieved by any of the alternative plans are considered to be incidental to the storm damage reduction objectives of the study. The storm damage mechanisms are briefly described in the following paragraphs.

227. *Long Term Erosion Damage.* Generally, erosion damages refer to the long-term loss of dry land area due to deficits in littoral sediment transport, impact of sea level rise and the long-term net impact of storms. Long term erosion may itself cause economic losses and will reduce the amount of protective beach area resulting in increased future storm damage.

228. *Storm Recession Damage.* The project area is subject to significant storm induced shoreline recession which becomes increasingly more damaging as long-term erosion reduces the protective buffer of the beach. Unlike long-term erosion, which is assumed to be stopped by intervention at bulkheads and major access roads, storm recession occurs over a relatively short period of time during the course of a storm. Thus, storm recession is considered capable of impacting buildings, including those fronted by protective structures, such as bulkheads and dunes.

229. *Inundation Damage.* Flooding from the convergence of tides and storm surge coupled with waves running over the shorefront, or overtopping protective structures, and across dry land causes damage to homes, businesses and public facilities. The extent and severity of flooding is expected to increase in relation to continued increases in sea level.

230. *Wave Attack.* Structures along the oceanfront are subject to significant forces due to impacts of waves breaking against the structure or the run-up associated with waves breaking seaward of the structure. The forces associated with such waves, and the associated run-up, are capable of causing structural failure due to overturning or lateral displacement.

CYCLE 1 - INITIAL SCREENING OF SOLUTIONS CONSIDERED

231. In Cycle 1 storm damage reduction measures are identified and evaluated individually and in combination on the basis of their suitability, applicability and merit in meeting the planning objectives, planning constraints, economic criteria, environmental criteria and social criteria for the study. Without undertaking an in-depth analysis, the goal of Cycle 1 analysis screens out those alternatives which obviously do not fulfill the storm protection needs of the study or are inappropriate due to other factors such as prohibitively high costs that are associated with some of the alternatives. Judgements are made about each alternative based on knowledge gained from researching past reports, the professional experience of study team members and other District personnel. In addition, in the spirit of our partnership agreement with the non-federal sponsor, DNREC, each of the alternatives are evaluated and discussed in terms of the sponsor's views concerning it's effectiveness in meeting the needs along the coast.

232. Relative costs for each alternative solution are determined in a qualitative manner, as shown in Table 18. For this analysis relative costs are defined as the total cost of the project as compared

TABLE 18
REHOBOTH BEACH/DEWEY BEACH OCEAN FRONT
CYCLE 1 - FIRST LEVEL SCREENING RESULTS

Alternative	Technical Appropriateness	Meet Objectives?			Relative Cost	Further Consideration in Cycle 2?
		Erosion	Inundation	Wave Attack		
No Action	Provides no measures to prevent damages from storms or long term erosion for the study area.	No	No	No	None	No
Regulation of Future Development	Provides no measures to prevent damages from storms or long term erosion for the study area because there is virtually no undeveloped land.	No	No	No	Low	No
Nonstructural Alternatives	No. Involves the acquisition of all affected lands and structures either by purchase or through powers of eminent domain.	No	No	No	Very High	No
Berm Restoration	Yes. Berm pushes the breaker zone and the erosion profile seaward. Provides sacrificial sediment during storms as well as recreational beach.	Yes	No	Partial	Moderate	Yes
Berm and Dune Restoration	Yes. .Berm pushes the breaker zone and erosion and inundation profile seaward. Provides sacrificial sediment during storms as well as recreational beach. Dunes can provide buffer during storms and can provide aesthetic value by planting with dune grass. Dune grass helps to stabilize the dune for storm protection.	Yes	Yes	Yes	Moderate	Yes
Berm and Dune Restoration with Groin Field (Dewey Beach only)	Yes. Costs of the groin field must be offset by reduced periodic nourishment requirements. This option could also reduce long term erosion and stabilize Dewey Beach. Can cause down drift erosion.	Yes	No	Yes	High	Yes
Berm Restoration with Bulkheading	Yes. Bulkheads perform the same function as dunes but is more costly and may require toe protection.	Yes	Yes	Yes	High	Yes
Berm and Dune Restoration with Offshore Detached Breakwater	Partial. Costs must be offset by reduced periodic nourishment requirements.	Partial	No	Partial	Very High	No

Table 18 continued on next page.

TABLE 18 CONTINUED
REHOBOTH BEACH/DEWEY BEACH OCEAN FRONT
CYCLE 1 - FIRST LEVEL SCREENING RESULTS

Seawall	Yes. Seawall performs the same function as bulkhead and dune but is much more costly. There is debate that seawalls can exacerbate erosion.	Partial	Yes	Yes	Very High	No
Berm Restoration with Seawall	Yes. Seawall performs the same functions as bulkhead and dune but is much mire costly. There is a debate that seawalls can exacerbate erosion.	Partial	Yes	Yes	Very High	No
Perched Beach	Partial. Costs must be offset by reduced periodic nourishment requirements. Less viable in high wave energy environments.	Partial	No	Partial	High	No
Submerged Reef	Partial. Costs must be offset by reduced periodic nourishment requirements. Existing submerged reef in NJ has not retained beachfill.	Partial	No	Partial	High	No
Offshore Berm	Partial. Costs must be less than direct placement of material on beach. Success is highly dependent on wave conditions.	Partial	Partial	Partial	Low	No
Beach Dewatering	Partial. Technology/performance is still unproven for an open ocean coastal environment. Requires an initial beachfill placement. Costs would have to be offset by reduced nourishment requirements. Life cycle costs for implementation are unknown.	Partial	Partial	Partial	Moderate	No

to the without-project damages, or pool of potential benefits. The following paragraphs summarize the objectives and evaluation of each of the above alternative solutions considered in Cycle 1.

233. There are two categories of solutions considered for implementation in the Rehoboth Beach/Dewey Beach study area, namely, nonstructural measures and structural measures.

234. Nonstructural measures are those measures which control or regulate the use of land and buildings such that damages to property are reduced or eliminated. No attempt is made to reduce, divert, or otherwise control the rate of erosion.

235. Structural measures are generally those which act to block or otherwise interfere with inundation and erosive coastal processes or which restore or nourish beaches to compensate for erosion and block inundation.

236. Shore protection measures were evaluated individually and in combination on the basis of their suitability, applicability, and merit in meeting the specific needs, objectives and constraints of the study. The project alternative measures considered are as follows:

Nonstructural Measures

- No Action
- Regulation of Future Development
- Permanent Evacuation

Structural Measures

- Berm Restoration
- Berm and Dune Restoration
- Berm and Dune Restoration with Groin Field (Dewey Beach only)
- Berm Restoration with Bulkhead
- Berm and Dune Restoration with Offshore Detached Breakwater
- Seawall
- Berm Restoration with Seawall
- Perched Beach with Berm and Dune Restoration
- Submerged Reef
- Offshore Submerged Feeder Berm
- Beach Dewatering

237. It should be noted that the above alternatives (bulkhead, dune, seawall) were evaluated in configurations which would provide similar storm damage protection.

238. **No Action.** The no action alternative imposes no measures to provide erosion control, recreational beach or storm damage protection to structures landward of the beach front. This alternative solution would not check the continuing erosion of the beaches, nor would it prevent property from being subjected to higher storm damages from beach recession, flooding and wave

attack. The nine existing groins in Rehoboth Beach would eventually deteriorate, and force the State of Delaware to rehabilitate these groins at high cost, or risk further accelerating the loss of beach. This plan fails to meet any of the objectives or needs of the study. Therefore, this alternative was not considered in Cycle 2.

239. **Regulation of Future Development.** Regulation or land use controls could be enacted through codes, ordinances, or other regulations to minimize the impact of erosion on lands which could be developed for the future. This measure lends itself to relatively large, continuous undeveloped areas rather than developed areas. At this time there is virtually no oceanfront that is not developed. Therefore, additional regulation to prevent new development would have little impact. Since this alternative solution is not practical it was not considered further in the Cycle 2 analysis.

240. **Permanent Evacuation.** Permanent evacuation of the existing developed areas subject to inundation or erosion damages involves the acquisition of affected lands and structures either by purchase or, if necessary, through the exercise of powers of eminent domain. Following this action, all commercial, industrial and residential property in areas subject to erosion or inundation damages are either demolished or relocated to another site. Undoubtedly, roads, railroads, water supply facilities, electric power, and telephone and sewerage utilities would also have to be relocated. The lands acquired in this manner could be used for undeveloped parks, or other purposes, that would not result in material damage from erosion or inundation. The towns of Rehoboth Beach and Dewey Beach have been intensely developed and the Silver Lake region is currently being developed. Any structures to be relocated would almost certainly have to be placed outside of the existing town limits. Due to the level of development in the study area, this alternative solution would be prohibitively expensive and does not meet the objectives of the study. Therefore, this alternative was not considered in Cycle 2.

241. **Berm Restoration.** This alternative involves the placement of beach fill material (sand), from offshore borrow source, directly onto the beach in order to widen and stabilize the existing berm profile. Usually the sand is pumped onto the existing shore using a dredge. An appropriate design uses borrow material that has similar properties to the existing native beach sand. In addition, the restored beach is graded to a certain design elevation and width to provide the desired level of storm protection. The constructed berm requires additional sand placement, renourishment, on a periodic basis so that the design berm width and elevation is maintained. Because this alternative meets the study objectives, has a moderate relative cost and is technically feasible it was considered further in Cycle 2 for the entire study area.

242. **Berm and Dune Restoration.** This alternative provides the same berm restoration effort as described above with additional sand placed upland of the beach to create a dune at a designed elevation and width. The dune provides additional storm surge protection similar to that of a bulkhead. Because this alternative meets the study objectives, has a moderate relative cost and is technically feasible, it was considered further in Cycle 2 for the entire study area.

243. **Berm and Dune Restoration with Groin Field.** This alternative provides the same berm and dune restoration effort as described above. Groins are coastal structures built perpendicular to the shoreline and are designed to trap some of the littoral drift. The typical groin extends from the upper beach face into the surf zone. A properly designed groin field will reduce erosion, and, when done in tandem with a beachfill project, will reduce the frequency of needed beach renourishment. However, a groin field will not provide adequate protection from storm surge. For this reason a groin field would only be included in the Federal project for if its cost is offset by the savings realized from a decrease in cost for periodic nourishment of the berm. Because this alternative solution meets the study objectives, may decrease renourishment costs enough to justify itself and is technically feasible it will be considered further in Cycle 2 for Dewey Beach which currently lacks a groin field. In Rehoboth Beach all of the groins are in fair physical condition and appear to be functioning adequately with the exception of the three northernmost groins in the study area. While these three groins continue to function, they are in poor condition and are exposed to the predominant wave action from the northeast and have been damaged in recent storm events. Modification of existing groins at Rehoboth would only be addressed if the selected plan would require a redesign of the current groin field.

244. **Berm Restoration with Bulkhead.** This alternative provides the same berm restoration effort as described above with the addition of a bulkhead. A bulkhead protects upland areas from erosion and inundation damage. Since 30% of Dewey Beach and 14% of Rehoboth Beach have existing timber bulkheads parallel to the ocean front, this alternative examined extending the timber bulkhead walls along the entire length of the study area. While the bulkhead will protect upland areas from inundation, beach restoration will limit erosion in front of the bulkhead and hence will provide additional protection to upland areas. This alternative meets the study objectives, has a high, but possibly acceptable, relative cost and is technically feasible for the study area, therefore this alternative was considered further in Cycle 2.

245. **Berm and Dune Restoration with Offshore Detached Breakwater.** This alternative provides the same berm and dune restoration plan as described above with the addition of an offshore detached breakwater along the length of the study area. The offshore detached breakwater is a structure which reduces the incident wave energy impacting the beaches thus reducing erosion. In many cases the offshore detached breakwater is a series of rubble mound structures that are visible from the beach during periods of low tide. The berm and dune restoration aspect of this option provides the needed storm protection. Since an offshore detached breakwater does not protect against storm surge, the required initial beachfill is the same as described above for the berm and dune restoration alternative. In order to be included in the Federal project the cost of this alternative solution would have to be offset by the savings from a decrease in periodic nourishment costs and reduced wave energy during a storm. In addition, this alternative has many other problems: constructability, aesthetics, and safety. Since construction of the breakwater must be done entirely from the water, all construction materials must be brought in on barges and all equipment used must be secured to jack-up barges. This effort introduces the additional difficulty of working in an open ocean environment. For these reasons the cost to construct an offshore breakwater in the open ocean environment would not be offset by a decrease in cost for periodic nourishment and reduced wave

energy during a storm. Therefore, the relative cost was determined to be prohibitively high. Therefore, this alternative was not considered in Cycle 2.

246. **Seawall.** This alternative includes the construction of a "Galveston type" seawall placed along the entire length of the study area, replacing all existing dunes, with a top elevation of +20' NGVD to prevent overtopping from a 50 year storm event. This structure includes fronting toe scour stone protection, pile supports and underlying sheeting to reduce underseepage. This alternative solution would not provide any recreational berm restoration but would provide storm damage protection consistent with other structural alternatives. It was determined that the relative cost for such a project would be prohibitively high. For this reason this alternative was not considered in Cycle 2.

247. **Berm Restoration with Seawall.** This alternative consists of the same berm restoration plan as described above with the addition of a "Galveston type" seawall also as described above. However, the cost for this alternative would not be offset by savings from reduced inundation and would therefore be prohibitively high. Therefore, this alternative solution was not considered in Cycle 2 for the same reasons that the seawall alternative above has been eliminated.

248. **Perched Beach with Berm and Dune Restoration.** This alternative provides the same berm and dune restoration plan described above with the addition of a submerged stone rubble mound structure which is used to support the offshore end of the placed beachfill. The placement of the rubble mound structure would eliminate the outer part of beach profile near its closure with the ocean bottom. Therefore, the actual amount of fill material to be placed is less than in the berm and dune restoration alternative. The submerged rubble mound structure acts in the same way as the natural bar formed offshore during storm events creating a "perched beach" with a wider berm. The main problem with this alternative is that angled swell scours in front of and behind the offshore structure resulting in the need for heavy maintenance to keep the structure functioning. In addition, interception of littoral drift will cause erosion downcoast. Due to the high expenses needed to maintain this structure and the fact that perched beaches are usually associated with reclamation, in lower wave energy environments, which is not an objective of this study, this alternative was not considered in Cycle 2.

249. **Submerged Reef.** This alternative solution involves the use of interlocking concrete units which form an offshore reef. This reef is intended to dissipate incident wave energy during storms, and to prevent outgoing currents from carrying sand to deeper water. Experience to date with this alternative along the New Jersey shore is still questionable. The units have a tendency to sink and the installation off Avalon, NJ has some of the erosion problems associated with the perched beach concept. In addition, there is a high cost associated with this alternative. Therefore, this alternative was not considered further in Cycle 2.

250. **Offshore Submerged Feeder Berm.** Potentially high costs associated with onshore placement have led to the development of alternative less expensive methods of beach nourishment. One such method is nearshore berm placement. In some areas, nearshore berms can reduce wave damage and provide sand to the littoral system with a cost as little as half that of onshore placement

(Allison and Pollock, 1993 and McLellan et. al, 1990).

251. Prototype experience with offshore submerged feeder berms is limited, and proper design techniques are still being researched and developed. For the berm to function successfully as a beach nourishment technique, several factors such as berm depth, wavelength, wave height and wave velocity must be within suitable ratios (Hands and Allison, 1991). Long term sediment transport trends, both longshore and cross-shore, must be examined. Berm placement site must be an appropriate distance down drift of an inlet or jetty to reduce the tendency of the sediment to return to the inlet or be caught by the jetty (McLellan et. al, 1990).

252. Because nearshore placement has had mixed results and current design techniques are limited and unproven, nearshore placement is a higher risk option than direct onshore placement at Rehoboth Beach and Dewey Beach. Also, because nourishment areas are located adjacent to the potential borrow sources, the difference in cost between direct onshore and nearshore placement may not be significant. Therefore, this alternative was not considered further in Cycle 2.

253. **Beach Dewatering.** The concept of beachface drainage as a method to increase beach stability has been tried in Florida and Denmark. Sand in the swash zone is typically in a buoyant state. Erosion is diminished by beach dewatering due to the discontinuity in the water table and the drained sand, and due to the intergranular pressure and stability which occurs because of the vertical downward flow of water. Accretion is promoted because the sediment laden swash is absorbed by the dewatered sand, causing a deposition of new sand on the foreshore slope.

254. Beach dewatering technology and performance is still unproven for an open ocean coastal environment. Tests have been completed on a small scale but should not be extrapolated to a large project such as this. Costs would have to be offset by reduced nourishment requirements. Life cycle costs for a large scale implementation are unknown. For these reasons, this alternative was not considered further in Cycle 2.

CYCLE 2 - IN DEPTH EVALUATION AND SCREENING OF SOLUTIONS CONSIDERED

255. The purpose of Cycle 2 is to further winnow down the number of alternatives that remain after Cycle 1 screening. Further screening of alternatives in Cycle 2 is accomplished through a comparison of annualized cost and the effectiveness of each alternative to provide protection from storm damage. In addition, consideration is given to periodic nourishment as well as alternative borrow sources. Only those alternatives that are practical, in terms of the engineering, economics, environmental and social impacts will remain after the completion of Cycle 2.

256. Since all of the plans to be analyzed in Cycle 2 include some aspect of beachfill placement an investigation was undertaken to identify a suitable borrow source. The utilization of an upland borrow source was ruled out due to the volume of sand needed for a beachfill project in the study area, distance of such sources, the expense of retrieving sand from these sources and impacts on the

roads and the local economy resulting from transporting the sand from the borrow source to the beaches. The following sections discuss the investigation conducted by the Philadelphia District to identify an offshore sand borrow source.

257. **Previous Investigations.** Initial sampling off the Delaware coast was performed for the Atlantic Coast of Delaware General Design Memorandum in 1975. Three vibracores, KHV-9 through KHV-11, were performed in the Hen and Chickens Shoal area. In these cores the material consisted of fine to medium sand with a gravelly zone in KHV-11 between 11 and 15 feet below the surface. An additional four cores were performed in an area 2.5 miles southeast of Dewey Beach however the sand was too thin for practical use and therefore, precluded further investigation in this area.

258. **Offshore Borrow Investigation.** The reconnaissance study report identified borrow areas for the entire Delaware Coast based upon previous investigations. In order to specifically identify sources of sand borrow for beach replenishment at Dewey and Rehoboth Beaches, a geoacoustic survey of the entire Delaware Coast was performed for the Philadelphia District by the U.S. Army Corps of Engineers Waterways Experiment Station (WES). This information coupled with 27 new vibracores was used to map all sediments, beneath the bottom from 0.5 miles to 3.5 miles offshore, covering the area from Cape Henlopen to Fenwick Island at the Maryland border. Due to the proximity to the project site and the cost involved in transporting material, only the area north of Indian River Inlet was considered as potential for borrow for Rehoboth Beach and Dewey Beach. Figure 23 shows the location of the vibracores and an outline of potential sand sources identified by the study. Use of the recently developed acoustic system in addition to the vibracore exploration enabled the district to save a substantial amount of money while compiling an unprecedented record of offshore deposits.

259. **Geoacoustic Subbottom Profile.** An acoustic survey of the Delaware Coast from Cape Henlopen to Fenwick Island was conducted 27 September 1992 to 2 October 1992. The entire area off the Atlantic coast of Delaware was surveyed at this time. The future studies at Bethany Beach and Fenwick Island will benefit from this survey. The survey was performed by WES, aboard the University of Delaware research vessel "Cape Henlopen". Multiple low frequency acoustic systems were deployed to provide data across the frequency spectrum between 500 and 5000 Hz. Both digital and analog reflection data were collected. The survey control and positioning were provided by Gahagen and Bryant Associates using a Differential Global Positioning System (DGPS). High frequency bathymetry information was also collected.

260. The technology utilized to define the subbottom characteristics was developed by WES. The geoacoustic survey was different than past Seismic surveys in that it utilized acoustic impedance to delineate grain sizes and densities within the sand gradation band. Stratigraphy sections were developed along the approximate 270 miles of survey lines. The information is invaluable to this project and all future work that is performed off the Delaware Coast. The Delaware Coast project is the first to utilize this technology in an ocean environment. The geoacoustic investigation of the Delaware Atlantic Coast from Cape Henlopen to Fenwick Island is contained in the Appendix A,

261. **Offshore Vibracore Investigation.** Twenty-seven vibracore samples, KHV-31 to KHV-58, were collected by Alpine Ocean Seismic Survey, Inc. in the Atlantic Ocean off the coast of Delaware, within the limits of the acoustic survey. See Figure 23 for sampling locations. Cores KHV-31 through KHV-42 were performed in the area north of Indian river Inlet, considered the area under investigation for this project. The samples were collected from 7 June 1993 through 17 June 1993 to depths 20 feet below the bottom. The field work included positioning of the vessel, obtaining continuous core samples by vibration, field logging of the samples and obtaining penetrometer records. The field work was conducted aboard the research vessel "Atlantic Twin". Scientific Environmental Application, Inc. performed the geotechnical analysis of the vibracore samples. Data from the vibracore investigation was used to calibrate and confirm data collected in the acoustic survey. Vibracore logs and gradation test results are contained in Appendix A, Section 4.

262. **Beach Sampling.** The State of Delaware conducted a beach sampling program for the Philadelphia District. Samples were collected following procedures outlined in the US Army Corps of Engineers Coastal Engineering Technical Note titled "Native Beach Assessment Techniques for Beach Fill Design" (CETN II-29 dated 12/91). Samples were obtained along 39 historical survey lines (LRP-38 through LRP-67) on the coast from Cape Henlopen to Fenwick Island. Two sets of beach samples have been collected to account for seasonable variability of the sediments. The summer beach was collected in August 1993; the winter beach was collected in December 1993 and March 1994. The winter sampling was split due to the loss of the sampler during the December sampling. The samples were recovered at midberm, berm crest, mean high tide, mid-tide, mean low tide, -6, -12, -18, -24, and -30 feet NGVD, to accurately define the grain size of the entire active beach profile. Six of the survey lines are located in the Dewey-Rehoboth area, spaced every mile through the project area (LRP-44 through LRP-49). Additionally samples were collected at MHW, mid-tide, and MLW at 20 stations along Dewey and Rehoboth Beaches as a quality control check. Due to the voluminous nature of the test data, Table 19 summarizes the calculated composite mean and sorting values for each line within the project area. The locations of the survey lines are shown on Figure 24.

263. **Borrow Area Identification.** The results of the geoacoustic and vibracore investigation and analysis indicate that two potential sand borrow areas exist for the Rehoboth Beach/Dewey Beach area. These two areas are the only significant offshore sources of sand within reasonable distance to Rehoboth Beach and Dewey Beach. One of the areas is located approximately five miles southeast of Dewey Beach and contains in excess of 7,000,000 cubic yards of fine to coarse sands. However, due to the distance to the project area, this source was rated secondary when compared to the Hen and Chickens Shoal area. The primary borrow area identified for this project is located on the Hen and Chickens Shoal. The delineated borrow area is approximately 2.5 miles northeast of the project area. The 1120 acre area constitutes only about 20% of the shoal. This area is significantly larger than required for this project, however this provides a greater area to select the most suitable beachfill material for the project. The entire shoal contains over 50,000,000 cubic yards of sand, of which a minimum of 10,000,000 cubic yards is contained in the borrow area. The 50 year project requires

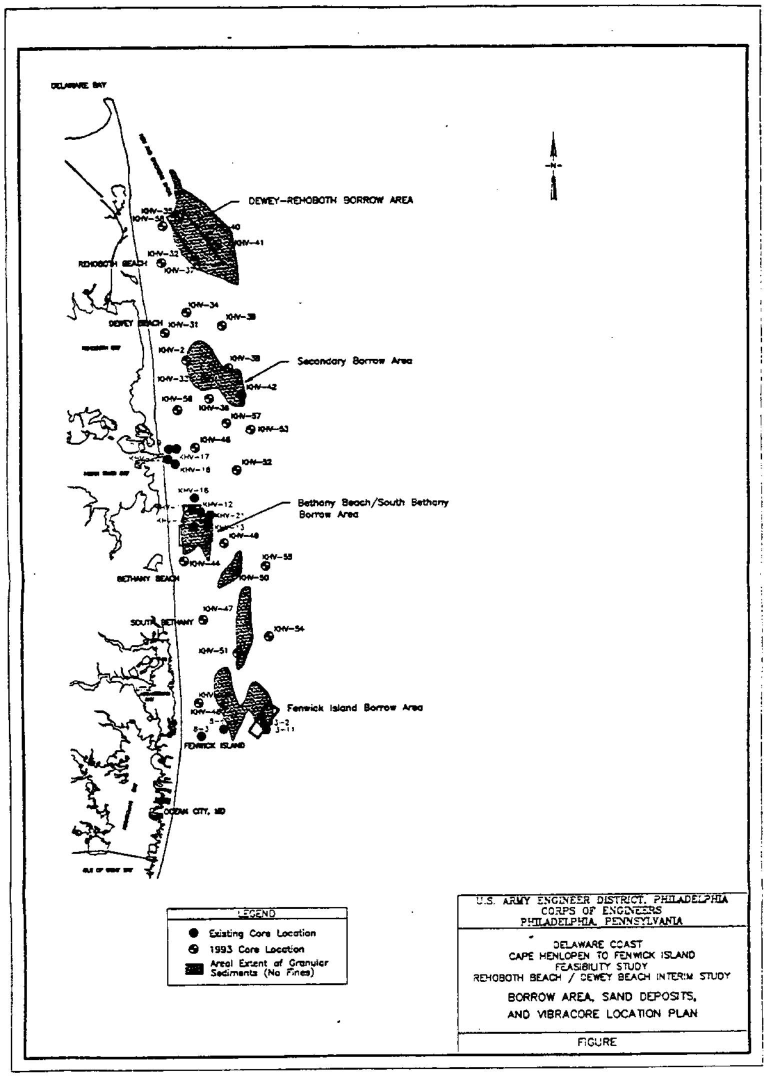

DEWEY-REHOBOTH BORROW AREA
Secondary Borrow Area
Bethany Beach/South Bethany Borrow Area
Fenwick Island Borrow Area
LEGEND
Existing Core Location
1993 Core Location
Areal Extent of Granular Sediments (No Fines)
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
DELAWARE COAST
CAPE HENLOPEN TO FENWICK ISLAND
FEASIBILITY STUDY
REHOBOTH BEACH / DEWEY BEACH INTERIM STUDY
BORROW AREA, SAND DEPOSITS,
AND VIBRACORE LOCATION PLAN
FIGURE

Figure 23

TABLE 19 SURVEY LINE MATERIAL COMPOSITE SUMMARY				
Composite Survey Line	Summer 1993		Winter 1993-94	
	Mean Diameter $M\phi$	Standard Dev. $\sigma\phi$	Mean Diameter $M\phi$	Standard Dev. $\sigma\phi$
LRP - 44	1.78	0.86	1.74	.81
LRP - 45	1.96	0.74	1.82	.95
LRP - 46	1.90	0.76	1.60	.88
LRP - 47	1.80	1.11	1.51	.82
LRP - 48	2.08	0.81	1.77	.88
LRP - 49	2.08	1.07	1.77	.76

approximately 7,000,000 cubic yards.

264. The borrow area for the Rehoboth Beach Dewey Beach Interim Feasibility Study is located within the State of Delaware waters (i.e. <3 miles offshore). Coordination has been performed with the Minerals Management Service (MMS) with respect to data exchange and exploration of sand sources. Approval from the MMS will not be required to utilize the borrow area for actual beach replenishment since it is within the State of Delaware territorial waters.

265. **Borrow Area Suitability Procedure.** Borrow material should be the same size, or slightly coarser, than the native beach material. If the borrow material has a significantly smaller grain size, the profile will be out of equilibrium with the local wave and current environment, and would be more quickly eroded either offshore or alongshore. The analysis compared the native sediment characteristics to the borrow material characteristics. The analysis was performed following the procedure developed by James (1975) and presented in the U.S. Army Corps of Engineers 1984 Shore Protection Manual. The analysis results in an "adjusted fill factor " or overfill factor, Ra, and a "renourishment factor", Rj. Ra estimates the volume of fill material needed to produce one cubic yard of stable beach material after equilibrium is reached, when the beach and native materials are compatible. Consequently, Ra values are greater than or equal to one. For example, an Ra factor 1.2 would indicate that 1.2 cubic yard of borrow material would be required to produce 1.0 cubic yard of stable beach material. This technique assumes that both the native and composite borrow material distributions are nearly log normal. Rj is a measure of the stability of the placed borrow material relative to the native beach sand. For example, an Rj factor of 0.33 would mean that renourishment using the borrow material would be required one third as often as renourishment using material on the beach.

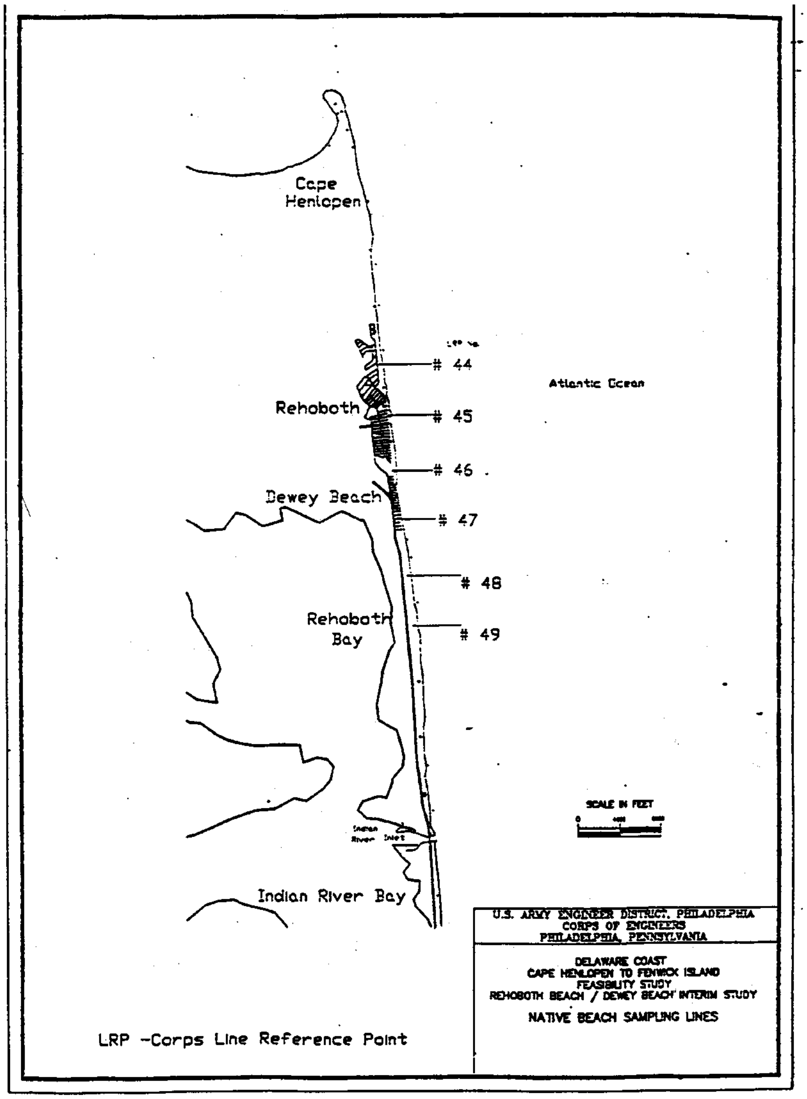

Cape Henlopen
Rehoboth
Dewey Beach
Rehoboth Bay
Indian River Bay
Atlantic Ocean
44
45
46
47
48
49
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
DELAWARE COAST
CAPE HENLOPEN TO FENWICK ISLAND
FEASIBILITY STUDY
REHOBOTH BEACH / DEWEY BEACH INTERIM STUDY
NATIVE BEACH SAMPLING LINES
LRP -Corps Line Reference Point

Figure 24

266. The borrow area for the Rehoboth Beach Dewey Beach Interim Feasibility Study is located within the State of Delaware waters (i.e. <3 miles offshore). Coordination has been performed with the Minerals Management Service (MMS) with respect to data exchange and exploration of sand sources. Approval from the MMS will not be required to utilize the borrow area for actual beach replenishment since it is within the State of Delaware territorial waters.

267. **Borrow Area Suitability Procedure.** Borrow material should be the same size, or slightly coarser, than the native beach material. If the borrow material has a significantly smaller grain size, the profile will be out of equilibrium with the local wave and current environment, and would be more quickly eroded either offshore or alongshore. The analysis compared the native sediment characteristics to the borrow material characteristics. The analysis was performed following the procedure developed by James (1975) and presented in the U.S. Army Corps of Engineers 1984 Shore Protection Manual. The analysis results in an "adjusted fill factor " or overfill factor, Ra, and a "renourishment factor", Rj. Ra estimates the volume of fill material needed to produce one cubic yard of stable beach material after equilibrium is reached, when the beach and native materials are compatible. Consequently, Ra values are greater than or equal to one. For example, an Ra factor 1.2 would indicate that 1.2 cubic yard of borrow material would be required to produce 1.0 cubic yard of stable beach material. This technique assumes that both the native and composite borrow material distributions are nearly log normal. Rj is a measure of the stability of the placed borrow material relative to the native beach sand. For example, an Rj factor of 0.33 would mean that renourishment using the borrow material would be required one third as often as renourishment using material on the beach.

268. **Native Beach Materials.** Utilizing the U.S. Army Corps of Engineers Automated Coastal Engineering System (ACES), composite beach grain size curves were developed for Dewey and Rehoboth Beach. Based on a winter and summer beach composites from the six survey lines in the project area, the mean grain size is 1.82 phi units (.28 mm), and the standard deviation in phi units is 0.85. This corresponds to a poorly graded or well sorted fine to medium sands. Table 20 summarizes the winter and summer composites of each line within the project area.

269. **Borrow Area Materials.** In general, the material encountered within the limits of the borrow area is a high quality beachfill consisting of well sorted fine to medium sands. The mean grain size ranges from 0.22 mm to 0.66 mm with the great majority falling between 0.28 mm and 0.34 mm. Results of this material sampling in addition to the vibracore analysis are included in Tables 20 and 21. Test results and logs are contained in Appendix A, Section 4. In the summer of 1994, after consultation and coordination with the district office, the State of Delaware utilized the Hen and Chickens area for an emergency beachfill at Dewey Beach.

TABLE 20 HEN AND CHICKENS BORROW AREA MATERIAL CHARACTERISTICS				
Vibracore	Mean Grain Size, $M\phi$	Standard Deviation, $\sigma\phi$	Overfill Factor, Ra	Renourishment Factor, Ri
KHV-35	1.8	0.45	3.0	1.6
KHV-37	0.6	0.9	1.0	0.2
KHV-40	2.2	0.2	>10.0	2.8
KHV-41	1.6	0.3	3.5	1.3
'94 Dewey Beachfill	1.7	0.5	1.5	1.4

TABLE 21 SECONDARY BORROW AREA MATERIAL CHARACTERISTICS				
Vibracore	Mean Grain Size, $M\phi$	Standard Deviation, $\sigma\phi$	Overfill Factor, Ra	Renourishment Factor, Ri
KHV-33	1.75	0.5	1.6	1.5
KHV-42	-0.08	1.87	1.03	<0.02

270. **Compatibility Analysis.** The suitability of the borrow area material was determined using the overfill ratio (USACE, 1984) combined with engineering judgement. The overfill ratio indicates the volume of borrow area material necessary to equal one cubic yard of native beachfill. Using sediment characteristics shown in the following tables and the native beach characteristics, the phi mean difference ratio and sorting ratio was calculated. Using the Shore Protection Manual, (1984), overfill and renourishment factors were determined for individual vibracores and the material dredged from the area by the State of Delaware in 1994. Actually, the only two cores that are located within the borrow area limits are KHV-35 and KHV-37. Based upon the results of KHV-37 (overfill ratio = 1.0), and utilizing the acoustic geological cross sections through the borrow area, it is evident that sufficient quantities of high quality beach sand are available on the shoal. In addition, the 1994 Dewey beachfill has proven to be successful one year after placement. The material is coarser than the native sediments, however the calculated overfill factor is 1.5. This is mainly due to the well sorted nature of the sediments.

271. The overfill factor has to be used with caution when the borrow area is coarser and better sorted than the beach. James(1975) indicates that when the borrow material is better sorted than the beach, that there is insufficient material in the grain size distribution and that sorting losses are not required. This is exactly the case for the Hen and Chickens Borrow Area when compared to Dewey and Rehoboth beaches.

272. The results of the vibracore and acoustic survey combined with sediment analysis of the 1994 Dewey beachfill, were used to evaluate the suitability of beach sands. Based upon this data, and taking into account the well sorted nature of the borrow, an overfill factor of 1.0 would be appropriate. However, in order to provide added security against large storm events and to account for areal variations in material type, an overfill factor of 1.2 was chosen for the project.

273. **Overfill Factor Application.** The overfill factor, as previously stated, is the amount of borrow material required to produce 1.0 cubic yard of native beach material after sorting losses. Sorting losses will occur during a period after initial placement as the active profile is subjected to continuous wave and current energy. Equilibrium is reached as the finer material is sorted from the profile.

274. In the District and throughout the Corps, it is common practice to place the first nourishment cycle along with the placement of the initial quantity required. This ensures that the level of protection for the beach remains throughout the first cycle of erosion. Theoretically, at the end of the first cycle, the advance nourishment quantity has eroded and the second nourishment cycle quantity is placed. The design template remains intact. This cycle will be repeated through the 50 year project life. This methodology demonstrates that the initial beachfill quantity that is placed is actually never exposed to the energy that sorts the beach sediments. Only the advanced nourishment quantity and subsequent renourishment quantities comprise the "active profile". Therefore, the borrow area overfill factor (1.2), has only been applied to the aforementioned nourishment quantities.

275. **Further Investigations.** In the next phase of this project, during preparation of plans and specifications, additional vibracores and associated material testing within the delineated borrow area will be performed to establish the exact location of the most suitable beachfill for the project.

PLANS CONSIDERED IN CYCLE 2

276. The following sections describe the plans considered for further analysis in the study area. General designs for this phase of screening were chosen after reviewing accepted coastal engineering practice, existing conditions in the study area, results of the without-project analysis, the Shore Protection Manual and CETN II-5. Table 22 discusses the technical performance, economic analysis, environmental and social impacts and annualized costs associated with each plan.

TABLE 22
REHOBOTH BEACH/DEWEY BEACH OCEAN FRONT
CYCLE 2 - SCREENING RESULTS

Alternative	Preliminary Design Considerations	Environmental Considerations	Social Considerations	Preliminary Annualized Costs (000's)	Total Without-project Annualized Damages (000's)	Further Consideration in Cycle 3?	Remarks
Berm Restoration	Fill existing berm out to 100', +8' NGVD elevation, for the entire study area.	Can smother and/or kill organisms in borrow area. Can increase nesting and beach habitat and enhance backshore environment.	Provide usable beach area.	$1492	$3440	Yes	Adverse environmental impacts can be minimized through coordination with environmental agencies.
Berm and Dune Restoration	100' Berm, +8 ft. NGVD. Dune: 25 ft top width, +14 ft. NGVD.	Can smother organisms and kill organisms in borrow area. Can increase nesting and beach habitat and enhance backshore environment.	Provide usable beach area. Dunes may cause some inconveniences to residents.	$1565	$3440	Yes	Adverse environmental impacts can be minimized through coordination with environmental agencies.
Berm and Dune Restoration with Groin Field (Dewey Beach only)	Dewey Beach: same as berm and dune restoration with the addition of timber groins with armor stone protecting the seaward third. Groins would be 300' in length and spaced 750' apart.	Same as berm and dune restoration although some construction is performed in submerged lands.	Same as berm and dune restoration but there may be aesthetic problems with hardened structures.	$1930	$3440	Yes	Costs must be offset by reduced periodic nourishment requirements and reduction in the long term erosion rate.
Berm and Dune Restoration with Bulkhead	Timber sheeting anchored with timber piles 30' long with 12" diameter. approx. 11,150 l.f. along study area.	Same as berm and dune restoration.	Same as berm and dune restoration.	$2238	$3440	No	Bulkheads perform the same function as dune but are more costly. Road ends are existing low points in elevation.

277. **Berm Restoration.** A typical sections for berm restoration along the study area is shown in Figure 25. The design berm having a height of +8 ft NGVD, a design width of 100' and a foreshore slope of 1V:15H was chosen. The sand would be placed over a length of approximately 13,000 l.f. along Rehoboth Beach, the Silver Lake Region and Dewey Beach. The sand borrow source is located approximately 2.5 miles offshore in approximately 30 feet of water. The beachfill quantities used for cost estimating purposes were obtained using the typical sections and lengths mentioned above. Preliminary annualized cost estimates for construction of the berm restoration alternative is shown in Table 22. When compared to the annualized damages, it can be seen that this alternative is relatively inexpensive. Therefore, this item will be considered in Cycle 3.

278. **Berm and Dune Restoration.** Consists of the same berm restoration plan, as stated above, a 100 ft design berm width, on top of which is a dune with an elevation of +14 ft NGVD, a top width of 25 ft. and side slopes of 1V:5H. The dune extends for the length of the study area, approximately 13,000 feet. A preliminary design section of this alternative solution is shown in Figure 26.

279. Annualized cost estimates for construction of the berm restoration and dune are shown in Table 23. When compared to the annualized damages it can be seen that this alternative is relatively inexpensive. This alternative will be considered further in Cycle 3.

280. **Berm and Dune Restoration with Groin Field.** The berm and dune would be designed as described above with the inclusion of a groin field in Dewey Beach. As mentioned previously, the existing groins in Rehoboth Beach are functioning well with the possible exception of the three northernmost groins in the study area. While these three groins continue to function, they are exposed to the predominant wave action from the northeast and have been damaged in recent storm events but are not in imminent danger of failing.

281. Eight groins would be constructed in Dewey Beach approximately 750' apart. A plan view of the proposed groin field and a cross section of a typical groin considered for the alternative are shown in Figures 27 and 28. The groin field would be constructed in conjunction with the berm and dune restoration plan as shown in Figure 26. The preliminary annualized cost estimates for construction of the berm and dune restoration along the entire study area with a new groin field for Dewey Beach are shown in Table 22. As can be seen this alternative is relatively inexpensive compared to the annualized damages. However, since the purpose of the groin field is to retain sand on the berm, and does not contribute to storm damage reduction, it will have to be justified by comparing the cost of construction against the savings realized from reduced periodic nourishment. In order to determine whether the construction of the groin field in Dewey Beach is justified on these grounds, this alternative solution will be considered further in Cycle 3.

282. **Berm Restoration with Bulkhead.** In addition to the berm restoration plan described above, a bulkhead would be constructed of timber pile and sheeting along the entire oceanfront of the study area. Timber piles 30' long and 12" diameter would be used to anchor the bulkhead into the ground. The beachfill design would not include a dune, since the bulkhead would provide similar storm surge protection. To protect the entire length of the study area would require the construction of

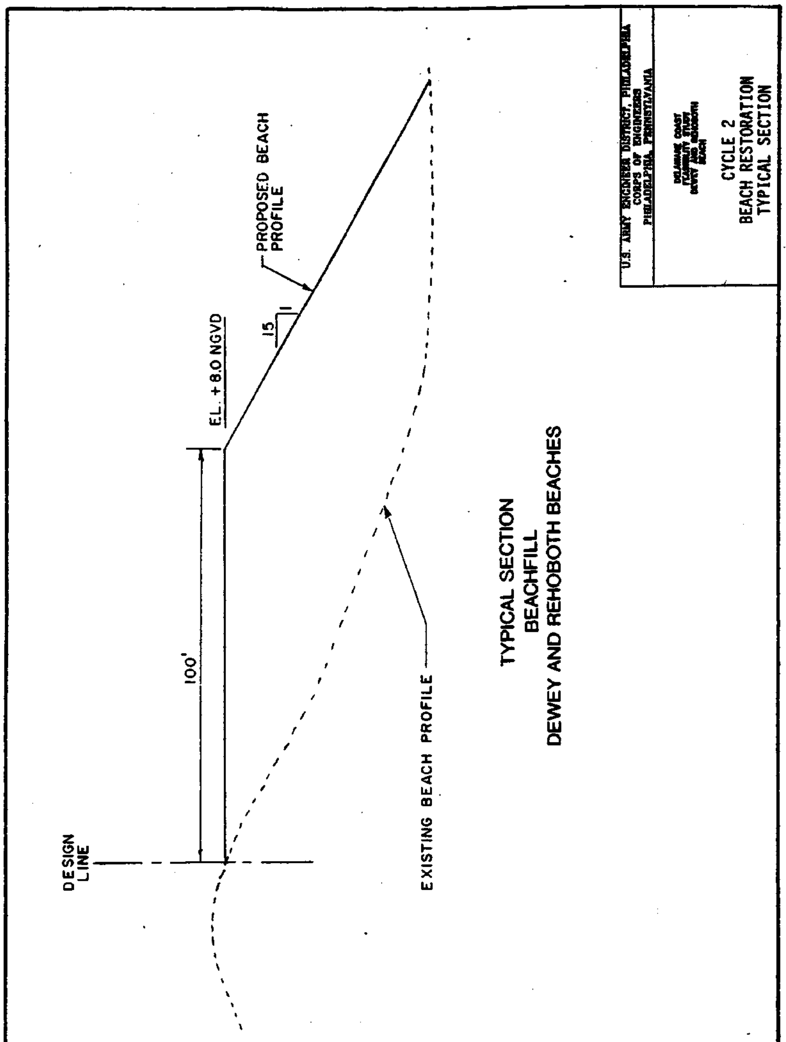

DESIGN LINE
100'
EL. +8.0 NGVD
15
1
PROPOSED BEACH PROFILE
EXISTING BEACH PROFILE
TYPICAL SECTION
BEACHFILL
DEWEY AND REHOBOTH BEACHES
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
CYCLE 2
BEACH RESTORATION
TYPICAL SECTION

Figure 25

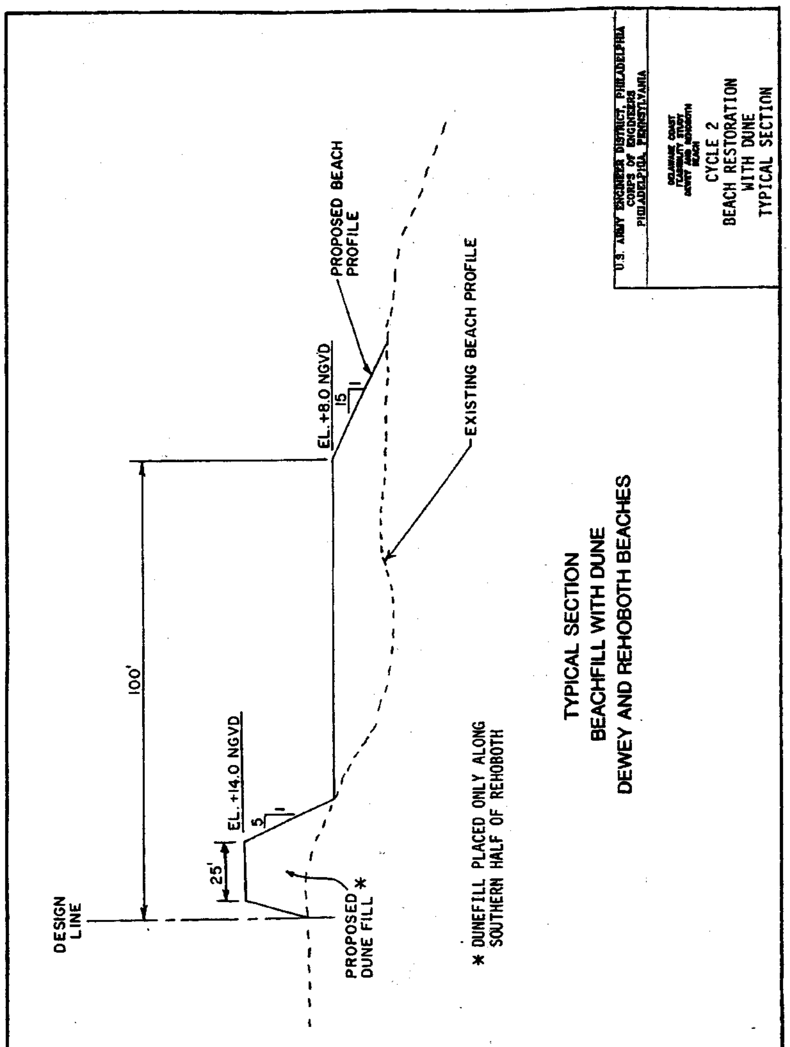
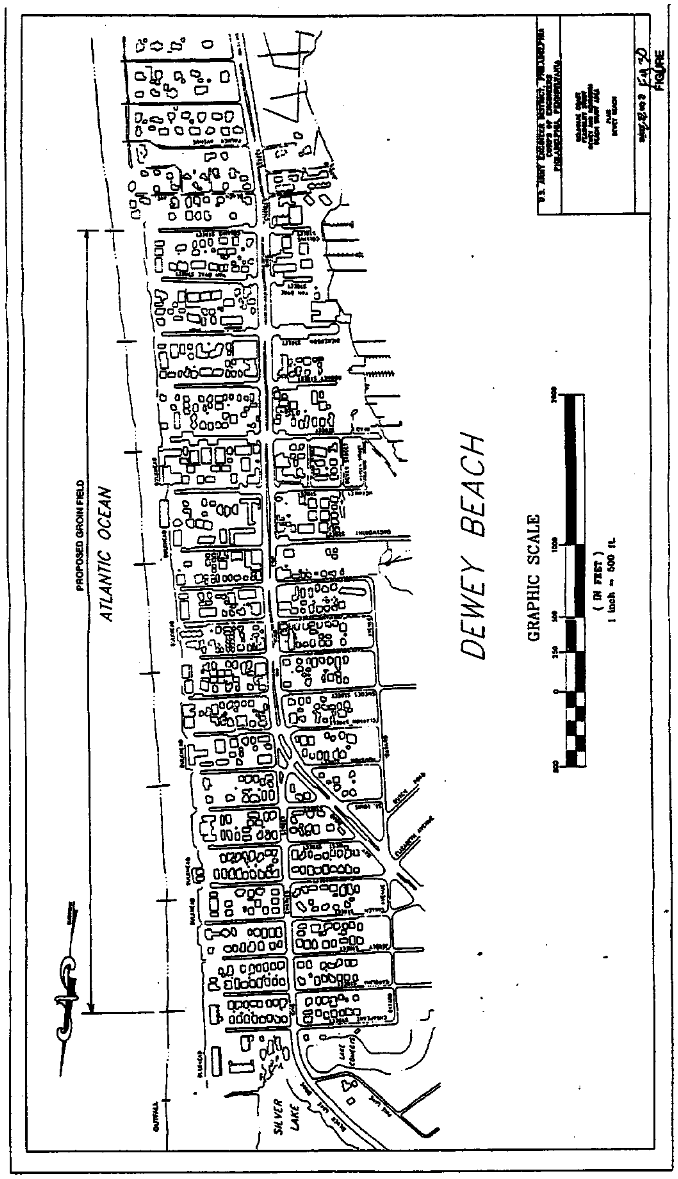
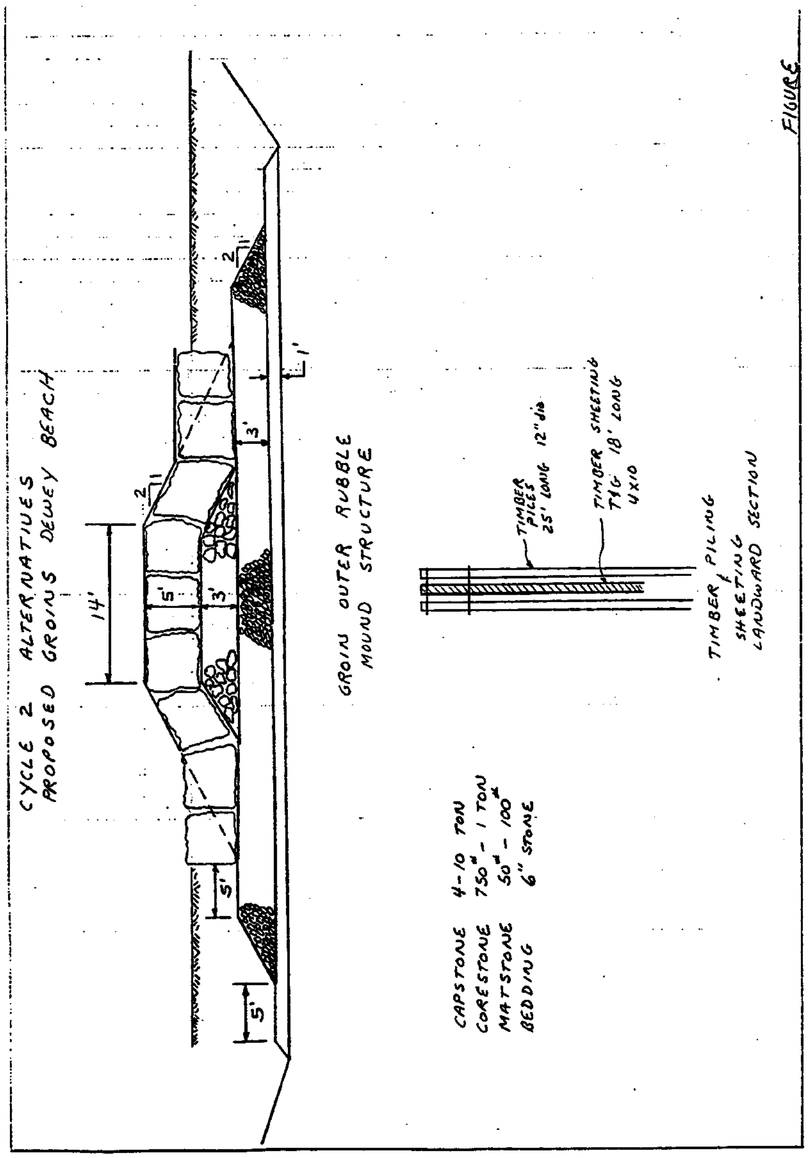

DESIGN LINE
100'
25'
EL. +14.0 NGVD
5
1
EL. +8.0 NGVD
15
1
PROPOSED BEACH PROFILE
EXISTING BEACH PROFILE
PROPOSED DUNE FILL *
* DUNEFILL PLACED ONLY ALONG SOUTHERN HALF OF REHOBOTH
TYPICAL SECTION
BEACHFILL WITH DUNE
DEWEY AND REHOBOTH BEACHES
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
CYCLE 2
BEACH RESTORATION
WITH DUNE
TYPICAL SECTION

Figure 26



PROPOSED GROIN FIELD
ATLANTIC OCEAN
DEWEY BEACH
GRAPHIC SCALE
(IN FEET)
1 inch = 500 ft.
SILVER LAKE
OUTFALL

Figure 27



CYCLE 2 ALTERNATIVES
PROPOSED GROINS DEWEY BEACH
14'
5'
3'
3'
1'
5'
5'
GROIN OUTER RUBBLE MOUND STRUCTURE
CAPSTONE 4-10 TON
CORESTONE 750# - 1 TON
MATSTONE 50# - 100#
BEDDING 6" STONE
TIMBER PILES 25' LONG 12" dia
TIMBER SHEETING T&G 18' LONG 4X10
TIMBER PILING & SHEETING LANDWARD SECTION
FIGURE

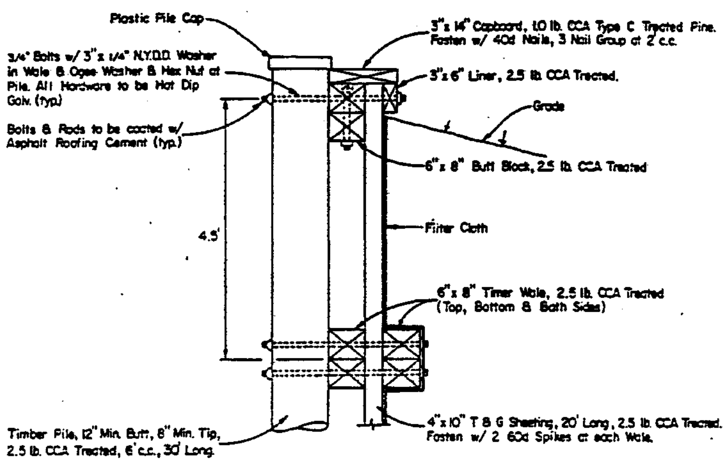
Figure 28

approximately 11,150 l.f. of bulkhead. The new bulkhead would tie into the existing sections of timber bulkhead along the ocean front. The beachfill placed shoreward of the proposed bulkhead would be identical to the berm restoration alternative described above. A typical section of the proposed bulkhead is shown in Figure 29. The preliminary annualized cost of this alternative is presented in Table 22. Even though this alternative meets the study objectives, the annualized cost is relatively high in proportion to the annualized damages. In addition, the bulkhead performs virtually the same function as a dune (as described above in the Berm and Dune Restoration alternative solution) but has a much higher relative cost. Therefore, this alternative will not be considered further in Cycle 3.

SOLUTIONS RECOMMENDED FOR OPTIMIZATION CYCLE 3

283. The Cycle 1 and Cycle 2 screening process eliminated most of the alternative projects considered in this study. The solutions recommended for optimization to determine the NED plan for the study area in Cycle 3 include;

- Berm Restoration
- Berm and Dune Restoration
- Berm and Dune Restoration with Groin Field (for Dewey Beach only)



TYPICAL SECTION
BULKHEAD

Figure 29

CYCLE 3- OPTIMIZATION OF THE SELECTED ALTERNATIVE SOLUTIONS

284. This section discusses the process undertaken to optimize the alternative solutions recommended from Cycle 2.

285. **Incremental Analysis.** In order to properly formulate the NED plan two discrete incremental reaches are established for this study, one for Dewey Beach and one for Rehoboth Beach. The intervening area of Silver Lake is equally divided between the two larger communities. The incremental reaches are based on existing economic and physical conditions, while also ensuring that the recommended project is constructable, and that each reach functions properly and independently. These reaches are based on the type and extent of development, dissimilarities in the typical beach and upland profiles comprising the without-project condition, and background erosion rate. Also taken into account is the existence of the groin field and predominantly bulkheaded shorefront at Rehoboth Beach. Sufficient differences exist in the without-project conditions for both Rehoboth Beach and Dewey Beach to effect project optimization. Therefore, incremental justification is warranted.

286. **Boundary Conditions.** The alternative of beach nourishment requires optimization of the berm width and the dune height for both Rehoboth Beach and Dewey Beach. The methodology followed to optimize these features is accomplished by varying parameters between a set of boundary conditions established at the beginning of the analysis. In developing these boundary conditions the Shore Protection Manual, CETN II-5, the existing conditions in the study area and accepted coastal engineering practice were reviewed. Listed below are the boundary conditions utilized to construct a logical methodology to efficiently identify the optimum plan.

Berm assumptions:

- Design berm heights for each alternative have an elevation set at the natural berm crest elevation as determined by historical profiles. It was determined that the prevailing natural berm height in the study area is +8 ft NGVD.

- The slope of the design berm is based on historical profiles and the average slope of the berm, both onshore and offshore. The prevailing historical foreshore slope within the project area is approximately 1V:15H. Seaward of the mean low water mark the beach slope is approximately 1V:25H. These slopes are used for the design berm out to the depth of closure.

- All berm widths are referenced from a design baseline which is in general alignment with the existing bulkhead line in Dewey Beach and the seaward edge of the boardwalk in Rehoboth Beach.

- The minimum design berm width considered is approximately the average width of the without-project condition along the length of the study area. This design alternative requires beachfill for some locations to establish a consistent berm height and includes advance nourishment along the entire study area to ensure a constant design template between nourishment cycles. The minimum berm width analyzed is 50 ft.

- The largest design berm width is based on an analysis of the average existing beach profile and determining how far offshore the design berm could go before the quantities required to construct such a berm clearly would increase faster than the additional benefits captured. It is also assumed that after a certain distance offshore the amount of benefits captured by larger berms would level out. Based on this analysis the largest berm width considered is 250 ft.

- An interval between berm widths is chosen so that the optimum berm width can more easily be identified. This interval is set wide enough to discern significant differences in costs and benefits between alternatives but not so great that the NED plan can not be accurately determined. In order to satisfy these criteria a 25 ft. interval is used.

- All beachfill alternatives include a taper at each project terminus to transition the constructed project into the existing condition beaches outside the project area. This is to reduce increased erosional losses due to discontinuities in the shoreline orientation. Guidance provided by the Shore Protection Manual and CETN-II-6 is utilized for designing the beachfill tapers.

Dune Assumptions:

- The lowest design dune height should be significantly above the height of the berm in order to provide for additional storm damage protection, principally in the form of reduced inundation and wave attack damages. Based on existing backshore elevations of +12 ft NGVD, results of the without-project analysis and historical dune performance during storms it was estimated that dune heights of +14 ft., +16 ft. and +18 ft. NGVD would be required to capture significant benefits within this study area are.

- Dune alternatives are designed so that the landward toe begins at the same design line used for the delineation of berm width. Based on existing dune heights and previous experience, each dune alternative is designed with a 25ft top width.

- The landward and seaward slopes of the design duneface is based on the existing profiles, and the grain size analysis of the existing beach and the material in the borrow area. From these analyses slopes of 1V:5H are used.

Groin Assumptions:

- A groin field is ultimately included in the selected plan if the cost of constructing the groin field is offset by the savings due to a reduction in the periodic nourishment quantity.

287. **Preliminary Screening of Beach Restoration Alternatives.** Based on the boundary condition assumptions discussed above, 36 combinations of berm widths and dune heights was generated. A preliminary evaluation of these combinations was performed in an effort to reduce the total number of hydraulic (SBEACH) and economic model runs utilized during the optimization analysis to identify the NED plan. Table 23 summarizes the full matrix of initial alternatives and the recommendations of the preliminary screening.

288. Some berm and dune alternatives were quickly identified as virtually non-constructable given the footprint requirements of the varying dune options as well as the toe protection required for dune stability. This eliminated 6 combinations from the matrix.

TABLE 23
MATRIX OF INITIAL ALTERNATIVES

DUNE HEIGHT (FEET NGVD)	BERM WIDTH (FEET)								
	50	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**
0	E	E	R	R	R	E	E	E	E
14	X	R	R	R	R	R	E	E	E
16	X	X	R	R	R	E	E	E	E
18	X	X	X	E	E	E	E	E	E

E = Eliminated in the preliminary screening analysis
R = Recommended for further analysis
X = Inappropriate design template

289. The remaining matrix of alternatives was then subjected to a screening consisting of limited model runs and quantity calculations. This initial screening was used to assess the performance of these alternatives within the study area and provide a basis for progression to the full analysis of benefits and costs.

290. The results of the initial screening indicated that berm widths in excess of 175 ft. resulted in exceptionally higher quantities without a commensurate increase in the performance of reducing the storm impacts. A similar conclusion was reached with dune heights in excess of +16 ft NGVD. An additional factor in screening out the larger berm widths is that they would also extend beyond the existing groin field in Rehoboth Beach which would increase nourishment requirements, and/or, add costs to modify the groins. For these reasons, an additional 15 alternatives were eliminated from the

matrix.

291. The two minimum berm-only alternatives (50 ft. and 75 ft.) only marginally provide for any reduction in erosion and little to no reduction in inundation and wave attack when compared to the without-project condition. It was also concluded that the largest remaining berm width (175 ft.) should only be analyzed with a dune with an elevation of +14 ft. NGVD. This was based on the general performance trend which indicated a noticeable improvement in performance of a dune with an elevation of +14 ft. NGVD over no dune, yet only a minor improvement between the dune with an elevation of +14 ft. NGVD and the dune with an elevation of +16 ft. NGVD.

292. Based on this initial screening, 11 alternatives remained in the matrix and were recommended for further analysis. The full list of beach restoration alternatives evaluated for project optimization is listed in Table 24.

TABLE 24
ALTERNATIVE PLANS CONSIDERED

ALTERNATIVE	DUNE HEIGHT	BERM WIDTH
PLAN 1	None	100'
PLAN 2	None	125'
PLAN 3	None	150'
PLAN 4	14'	75'
PLAN 5	14'	100'
PLAN 6	14'	125'
PLAN 7	14'	150'
PLAN 8	14'	175'
PLAN 9	16'	100'
PLAN 10	16'	125'
PLAN 11	16'	150'

OPTIMIZATION OF ALTERNATIVE PLANS

293. **General.** Benefits and costs for both Rehoboth Beach and Dewey Beach were developed for the alternative plans discussed above to optimize the NED plan in the study area. This was accomplished using the same numerical modeling techniques utilized in the without-project analysis coupled with engineering and technical assessments to interpret model results as applied to the various alternatives. Reduced damages based on the predicted reduction in storm impacts due to the with-project alternatives were compared to the without-project results to generate project benefits. Costs for each alternative were estimated based on standard construction practices and District experience in the construction of beach nourishment projects.

294. **Storm Impacts.** The with-project conditions are the conditions that are expected based on the predicted impacts of storm events on the various project alternatives. The periodic nourishment associated with the project is designed to insure the integrity of the project design. In the case of beachfill this ensures the project design cross section will be maintained and the elimination of shoreline recession due to long-term erosion. However, coastal processes will continue to impact the shoreline along the project area. Storm-induced erosion, wave attack and inundation were evaluated for the with-project conditions using the same methodologies utilized in the without-project analyses. The following sections describe the coastal processes which were used to estimate the with-project damages.

295. ***Storm Induced Erosion.*** The numerical model SBEACH was applied to predict storm-induced erosion for the with-project conditions for the study area. All SBEACH input variables were identical to the without-project runs except the input profiles were modified to include the alternative beachfill designs. As in the without-project condition, storm events from 5 to 500 year frequency were analyzed on the with-project alternatives. Model results were reviewed and analyzed for reasonableness as applied to the varying with-project alternatives. A summary of the with-project erosion results is presented in Appendix A, Section 2.

296. ***Storm Inundation.*** The post storm recession profiles generated by SBEACH were used to analyze flooding and wave/run-up attack using the same methodology described in the without-project analyses. The wave height frequency and stage-frequency data utilized to assess the alternative designs was identical to that used for the without-project conditions. Appendix A, Section 2 lists the 3 foot damaging wave/run-up impact zones for the beachfill alternatives within each cell for the 5 through 500 year event as well as the total water elevation profile. Similar inundation profiles were computed in order to determine the total water level across the beach profile and into the community.

297. **Nourishment Requirements.** In order to maintain the integrity of the design beachfill alternatives, beachfill nourishment must be included in the project design. If periodic nourishment were not performed throughout the life of the project, longshore and cross shore sediment transport mechanisms, separate from storm induced erosion, would act to erode the design beach. This erosion would reduce the protection from storm damage afforded by the project design. The nourishment

quantities are considered sacrificial material which acts to ensure the integrity of the project design. Various coastal processes were analyzed to develop an estimate of the required annual nourishment fill volumes.

298. The nourishment parameters were developed by considering long term historic erosion losses using shoreline recession rates developed for the sediment budget, volumetric analysis of recent beach profiles (1992 and 1993), beachfill losses due to the predicted rate of sea level rise, and losses due to storm induced dune erosion. The results of these analyses were compared and the volumetric requirements were combined to obtain the total nourishment needs for each of the project alternatives.

299. ***Long Term Rates.*** Utilizing the long term shoreline change rates and recent volumetric profile analysis, unique nourishment rates were determined for the southern (Dewey Beach) and northern (Rehoboth Beach) reaches of the project area. The long term erosion rates for Rehoboth Beach and Dewey Beach are 21,000 and 57,000 cubic yards per year, respectively. These rates represent required annual nourishment for the design alternatives. An additional nourishment quantity was included to maintain alternatives which include design dunes larger than the existing dune conditions.

300. ***Rate of Sea Level Rise.*** Using the current rate of sea level rise of 0.0102 feet per year, and the Bruun method, the distance of shoreline retreat over the 50 year project life was determined. This rate of retreat was combined with the long term erosion losses and dune erosion losses to develop the nourishment estimates. Table 25 presents the adopted nourishment estimates for the beachfill design alternatives.

TABLE 25
NOURISHMENT ESTIMATES
(1,000's CY/YR)

DUNE ELEV.[1] ALT	DEWEY BEACH	REHOBOTH BEACH	TOTAL
None	60	25	85
14'	70	30	100
16'	80	35	115
18'	90	40	130

[1] Elevations are given as feet above NGVD.

301. **Major Rehabilitation.** Major rehabilitation quantities were developed in accordance with

ER 1110-2-1407 to identify additional erosional losses from the project due to higher intensity (low frequency) storm events. The nourishment rates developed for the project alternatives include losses due to storms that have occurred within the analysis period, storms of approximately 50 year return period and more frequent are encompassed in those rates. Major rehabilitation losses are computed as the losses that would occur from the 50% risk event over the project life. The annual percent frequency event with a 50% risk during the 50 year economic project life is 1.37%. The period of record of stages recorded at the study area is approximately 73 years, and the storm of record was the March 1962 northeaster. This storm was not only the stage of record but also by far induced the greatest loss of beach material during the period. The 1962 northeaster was considered to be the 50% risk event for the purposes of the major rehabilitation analysis. SBEACH was employed to compute volumetric erosion from the selected beach alternative design profile utilizing the hydraulic input parameters from the 1962 northeaster. Water levels and waves were hindcasted at the study area for the storm, and all model parameters were identical to the without and with-project analyses. Volumetric storm induced erosion was computed within each cell for the design beach profile and then an average loss quantity was computed within Rehoboth Beach and Dewey Beach. The computed results show little variation in volumetric erosion between cells. Based on methodologies and experience developed at the Philadelphia, Wilmington and New York Districts, Corps of Engineers, it is has been estimated that between 60 and 75 % of the material displaced during large storms will return to the foreshore within weeks and only the remaining 25 to 40 % will require mechanical replacement. Therefore, as an estimate of the necessary major rehabilitation quantity, a volume equal to 50% of the estimated eroded volume will require mechanical placement onto the beach to regain the design cross-section and insure the predicted level of storm damage reduction.

302. It is estimated that volumes of 100,000 and 80,000 cubic yards within Rehoboth Beach and Dewey Beach, respectively, would be required to perform major rehabilitation in response to the 50% risk event over the project life.

303. **Economic Evaluation of Alternative Plans.** Economic benefits for the design alternatives are derived from the reduction in storm damages, reduced maintenance costs to existing structures and emergency/clean-up response costs, and recreation. Recreation is not a Federal priority benefit category and is not utilized in the optimization of the selected plan. The benefits leading to project optimization are summarized below and discussed in more detail in the Appendix B.

304. ***Storm Damage Reduction.*** The without-project conditions within the project area provide a low level of protection against storm damage. The beachfill design alternatives will reduce storm damage by reducing profile recession, flooding incurred due to high levels of ocean storm water elevations, and wave run-up and direct wave impacts. Damages for the with-project alternatives are calculated using the same methodologies and databases as previously detailed in the without-project conditions. The benefits for any given project are the difference between without-project damages and with-project damages.

305. ***Reduced Maintenance Benefits.*** In addition to storm damage reduction benefits, reduced maintenance benefits accrue under the with-project scenario.

306. The State of Delaware has decided to rehabilitate those groins in Rehoboth Beach that are in the most need of repair. This decision was made independent of any project resulting from the current feasibility study, and in fact was made before the initiation of the reconnaissance study in 1990. However, funding constraints did not allow the State to complete rehabilitating all of the groins at one time. In 1990 the State rehabilitated the groin located at Deauville by placing core stone and armor stone on the seaward 2/3 of the groin at a total cost of $163,000. The next three groins the State plans to rehabilitate are the three northernmost groins in Rehoboth Beach. Since these groins have been damaged by recent storm events the State has stated that they intend to rehabilitate them using the same design template that was used for rehabilitation of the Deauville groin. It is estimated that this work will be complete in years 2, 3 and 5 of the life of the proposed project, respectively. However, in the absence of a Federal beachfill project, in addition to placing additional stone on the groins the State has plans to rehabilitate existing timber sheetpile. The total cost for rehabilitating each groin is expected to be $300,000 per groin.

307. It is anticipated that due to the proposed berm and dune restoration plan for Rehoboth Beach, the rehabilitation of the three northernmost groins will not have to be as extensive if the proposed project is constructed. Since the design berm with associated advanced nourishment and periodic nourishment will provide protection to the groins in question, the costs incurred by the State to rehabilitate these groins will decrease by approximately half. Core and armor stone can be placed onto a smaller portion of the groin because the constructed berm, and periodic nourishment, will prevent flanking and damage to the landward portions of these groins. This scenario has been coordinated and confirmed with the non-Federal sponsor. It is anticipated that the cost for the State to rehabilitate each groin will decrease from $300,000 to $150,000. When these savings are combined for all three groins the annualized benefits amount to $28,000.

308. ***Economic Optimization.*** Optimization of the alternatives is based on the priority benefit category of storm damage reduction (including reduced maintenance) indexed to an October 1994 price level. Initial construction and nourishment costs for the with-project alternatives are presented in Table 26. These costs are annualized for comparison to the average annual benefits for individual project alternatives. As mentioned previously, recreation benefits are not used in the optimization procedure. Initial construction, periodic nourishment, and major rehabilitation costs are annualized over a 50 year project life at 7.75%. The average annual costs are subtracted from average annual benefits to calculate net benefits and select the optimal plan which maximizes net benefits.

TABLE 26
ALTERNATIVE PROJECT COSTS

INITIAL COSTS		
Option Dune Height/Berm Width	Total Quantity +Adv. Nour. (Cubic Yards)	Total Cost
0' + 100'	827,251	$5,362,780
0' + 125'	1,090,922	$6,368,812
0' + 150'	1,386,764	$7,751,210
14' + 75'	675,719	$4,949,684
14' + 100'	988,551	$6,374,000
14' + 125'	1,252,222	$7,295,158
14' + 150'	1,548,064	$8,171,183
14' + 175'	1,994,055	$9,759,894
16' + 100'	1,121,513	$6,923,113
16' + 125'	1,385,184	$7,746,676
16' + 150'	1,681,026	$8,522,676

PERIODIC NOURISHMENT COSTS (3 YR CYCLE)		
Options	Quantity (Cubic Yards)	Total Cost
No Dune	306,000	$2,972,203
+ 14	360,000	$3,304,997
+ 16	414,000	$3,531,075

309. A summary of the reduction in with-project storm damages for each project alternative is listed in Table 27. It was unnecessary to perform a full economic analysis of plans 3, 4, and 11 in Rehoboth Beach because a review of project performance, economics and costs during the optimization confirmed that the optimal plan had been determined with a smaller berm width alternative. This precluded the need for additional model runs. Tables 28 and 29 identify the optimized plan for Dewey Beach and Rehoboth Beach respectively. Included in these tables are the average annual benefits and costs, the net benefits and benefit-cost ratio for storm damage reduction for Rehoboth Beach. **Plan 7** which provides a 150 ft. berm and a dune with an elevation of +14 ft. NGVD is the optimal plan in Dewey Beach, while the optimal plan in Rehoboth is **Plan 6** which provides a berm width of 125 ft. and dune with an elevation of +14 ft NGVD.

310. **Groin Analysis.** Following the selection of the optimized beachfill alternative, groins were analyzed to determine whether the costs to construct them is offset by the savings due to the reduction in periodic nourishment. In the case of Rehoboth Beach, the optimized berm width does not protrude beyond the ends of the existing groin field. This groin field has historically functioned adequately, and is assumed to continue to do so in the future. This has been confirmed by the shoreline change analysis which showed the relatively low rate of long term erosion within the groin field at Rehoboth Beach. Therefore, groin modifications are not recommended for Rehoboth Beach.

311. Reduced nourishment rates within Dewey Beach were estimated for a groin field extending south from the existing groin field in Rehoboth Beach to the southern border of Dewey Beach. Given that the groin field expansion would be designed with a similar spacing and groin length as the existing Rehoboth Beach groin field, a reasonable estimate of the reduced nourishment quantity was obtained. It was estimated that the nourishment rates in Dewey Beach will become comparable to the prevailing rates within Rehoboth Beach. Table 30 presents the estimated nourishment requirement if a groin field is constructed in Dewey Beach as part of the selected plan.

312. The annualized cost of the proposed groin field is $365,000, while the annualized savings (benefits) in reduced periodic nourishment associated with construction of the groin field is $61,000. Therefore, the placement of a groin field in combination with Plan 7 at Dewey Beach is not justified.

TABLE 27
STORM DAMAGE REDUCTION BY ALTERNATIVE
(Nov. 1993 Price Level)

DEWEY BEACH

Alt. Plan	Berm Width (Ft)	Dune Height (Ft)	Without Project Storm Damages	With Project Storm Damages	Storm Damage Reduction Benefits	Percent Reduced
1	100	None	$2,566,000	$1,463,000	$1,103,000	43
2	125	None	2,566,000	1,172,000	1,394,000	54
3	150	None	2,566,000	1,042,000	1,524,000	59
4	75	14	2,566,000	1,213,000	1,353,000	53
5	100	14	2,566,000	946,000	1,620,000	63
6	125	14	2,566,000	796,000	1,770,000	69
7	150	14	2,566,000	717,000	1,849,000	72
8	175	14	2,566,000	639,000	1,927,000	75
9	100	16	2,566,000	845,000	1,721,000	67
10	125	16	2,566,000	756,000	1,810,000	71
11	150	16	2,566,000	673,000	1,893,000	74

REHOBOTH BEACH

Alt. Plan	Berm Width (Ft)	Dune Height (Ft)	Without-project Storm Damages	With Project Storm Damages	Storm Damage Reduction Benefits	Percent Reduced
1	100	None	$946,000	$541,000	$405,000	43
2	125	None	946,000	518,000	428,000	45
4	75	14	946,000	438,000	508,000	54
5	100	14	946,000	403,000	543,000	57
6	125	14	946,000	374,000	572,000	60
7	150	14	946,000	362,000	584,000	62
9	100	16	946,000	411,000	535,000	57
10	125	16	946,000	367,000	579,000	61

TABLE 28
DEWEY BEACH BENEFIT/COST MATRIX
(in $000s)

		75' BERM	100' BERM	125' BERM	**150' BERM**	175' BERM
	(In 000'S)		ALT. 1	ALT. 2	ALT. 3	
NO DUNE	AVERAGE ANNUAL BENEFITS		1,144	1,444	1,570	
	AVERAGE ANNUAL COSTS		968	1,027	1,088	
	BENEFIT-COST RATIO		1.2	1.4	1.4	
	NET BENEFITS		176	417	482	
		ALT. 4	ALT. 5	ALT. 6	**ALT. 7**	ALT. 8
+14' NGVD DUNE HEIGHT	AVERAGE ANNUAL BENEFITS	1,401	1,676	1,831	**1,911**	1,985
	AVERAGE ANNUAL COSTS	988	1,084	1,136	**1,174**	1,268
	BENEFIT-COST RATIO	1.4	1.6	1.6	**1.6**	1.6
	NET BENEFITS	413	592	695	737	717
			ALT. 9	ALT. 10	ALT. 11	
+16' NGVD DUNE HEIGHT	AVERAGE ANNUAL BENEFITS		1,780	1,872	1,950	
	AVERAGE ANNUAL COSTS		1,153	1,196	1,226	
	BENEFIT-COST RATIO		1.5	1.6	1.6	
	NET BENEFITS		627	676	724	

TABLE 29
REHOBOTH BEACH BENEFIT/COST MATRIX
(in $000s)

		75' BERM	100' BERM	**125' BERM**	150' BERM	175' BERM
	(In 000'S)		ALT. 1	ALT. 2	ALT. 3	
NO DUNE	AVERAGE ANNUAL BENEFITS AVERAGE ANNUAL COSTS BENEFIT-COST RATIO NET BENEFITS		412 389 1.06 23	436 467 0.93 -31		
		ALT. 4	ALT. 5	**ALT. 6**	ALT. 7	ALT. 8
+14' NGVD DUNE HEIGHT	AVERAGE ANNUAL BENEFITS AVERAGE ANNUAL COSTS BENEFIT-COST RATIO NET BENEFITS	517 450 1.15 67	552 467 1.18 85	**583** **488** **1.19** **95**	594 522 1.14 72	
			ALT. 9	ALT. 10	ALT. 11	
+16' NGVD DUNE HEIGHT	AVERAGE ANNUAL BENEFITS AVERAGE ANNUAL COSTS BENEFIT-COST RATIO NET BENEFITS		545 512 1.06 33	589 531 1.11 58		

TABLE 30

NOURISHMENT ESTIMATE WITH ADDITION OF GROIN FIELD IN DEWEY BEACH (1000's CY/YR)

DEWEY BEACH	REHOBOTH BEACH	TOTAL	REDUCTION
35	30	65	65

SELECTED PLAN

313. **Identification of the NED Plan.** The National Economic Development (NED) Plan is defined as that plan which maximizes beneficial contributions to the Nation while meeting planning objectives. Most of the beachfill plans considered meet the planning objectives in that they provide a degree of storm damage protection which is greater than the cost of implementation. The NED plan for Rehoboth Beach is beachfill with a berm width of 125 ft. and a dune with an elevation of +14 ft NGVD and for Dewey Beach the NED plan is beachfill with a 150 ft. berm width and dune with an elevation of +14 ft NGVD. These plans were chosen because they provided the maximum net excess benefits over costs based on storm damage reduction.

314. **Description of the Selected Plan.** This section describes the selected plan for the study area. Details of the selected plan are shown in Figures 29, 30 and 31.

- The proposed hurricane and storm damage reduction plan consists of one continuous project over the entire 13,500 feet of the project area (from the taper into Deauville in the north to the taper into North Indian Beach in the south). However, the project was optimized at slightly different beach widths since the project consists of two distinct areas, Dewey Beach which is a barrier island and Rehoboth Beach, which is a headland area. Therefore, to maximize NED benefits the two areas optimize at slightly different beach berm widths.

- For Rehoboth Beach a berm extending seaward 125 ft from the design line at an elevation of +8 ft NGVD. For Dewey Beach a berm extending seaward 150 ft from the design line at an elevation of +8 ft NGVD. Both berm plans have a foreshore slope of 1V:15H to mean low water (MLW). From MLW seaward the slope parallels the bottom out to the depth of closure. The beachfill extends from the northern border of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach, and tapers into the existing shoreline in the north end at Deauville and in the southern end at North Indian Beach, for a total length of 13,500 l.f.

- On top of both berm plans in both communities lies a dune with a top elevation of +14 ft NGVD and a top width of 25 ft. The landward and seaward slope of the dune face is 1V:5H.

- A total sand fill quantity of 1,437,000 cubic yards is needed for the initial fill placement in Rehoboth Beach and Dewey Beach.

- 19 acres of planted dune grass and 17,800 l.f. of sand fence for entrapment of sand on the dune and delineating walkovers and vehicle access ramps.

- 39 dune walkovers are provided (one at each street end) and 2 vehicle accessways over the dune (one for each town).

- Renourishment of approximately 360,000 cubic yards of sand fill from the offshore borrow area every 3 years for the 50 year project life.

- Beachfill for the proposed project is available from an offshore borrow area located approximately 3 miles offshore of the Rehoboth Beach/ Dewey Beach area.

- To properly assess the functioning of the proposed plan, monitoring of the placed beachfill, borrow area, shoreline, wave and littoral environment is included with the plan. Environmental monitoring is being addressed through coordination with other interested agencies, and is included in the final costs for this project. The proposed environmental monitoring plan is presented in Appendix A, Section 5.

315. **Summary.** This design is complete and is consistent with Corps criteria as described in the Shore Protection Manual, CETN-II-5, CETN-II-6 and accepted engineering practice. Additional design work (ie. a Design Memorandum) is not needed with the exception of a geotechnical borrow area investigation which can be completed concurrent with the development of plans and specifications.

316. **Transition Taper.** The selected plan incorporates a 1000 ft taper on either end of the constructed project. This taper is considered the minimum design necessary to ensure project integrity. The taper will transition into the existing beach berm in the northern end of the project area, at Deauville, and at the southern end, at North Indian Beach. It should be noted that North Indian Beach is a restricted access private beach community. However, the southern taper is an integral feature of the selected plan and provides benefits to the project which is exclusively formulated on the total public beach. Further, it provides only incidental benefits to the private beach (which were not included in project formulation), and has no negative down drift impacts. Therefore, the inclusion of the taper on these private lands is in accordance with Federal guidelines for Federal participation in the project.

317. The proposed tapering of the beachfill project on the northern and southern ends is the most economical alternative for terminating the proposed project. There are three possible alternatives to terminating the beachfill project, namely, a terminal groin, tapering the beachfill or ending the beachfill at the southern border of Dewey Beach and the northern border of Rehoboth Beach.

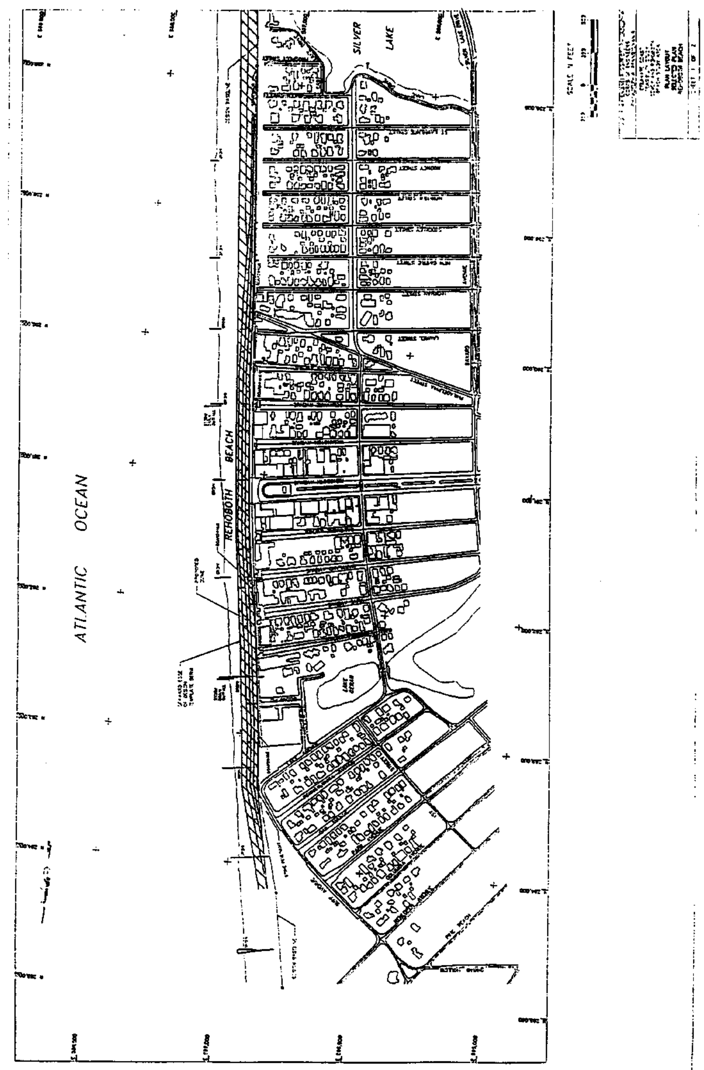


Figure 30

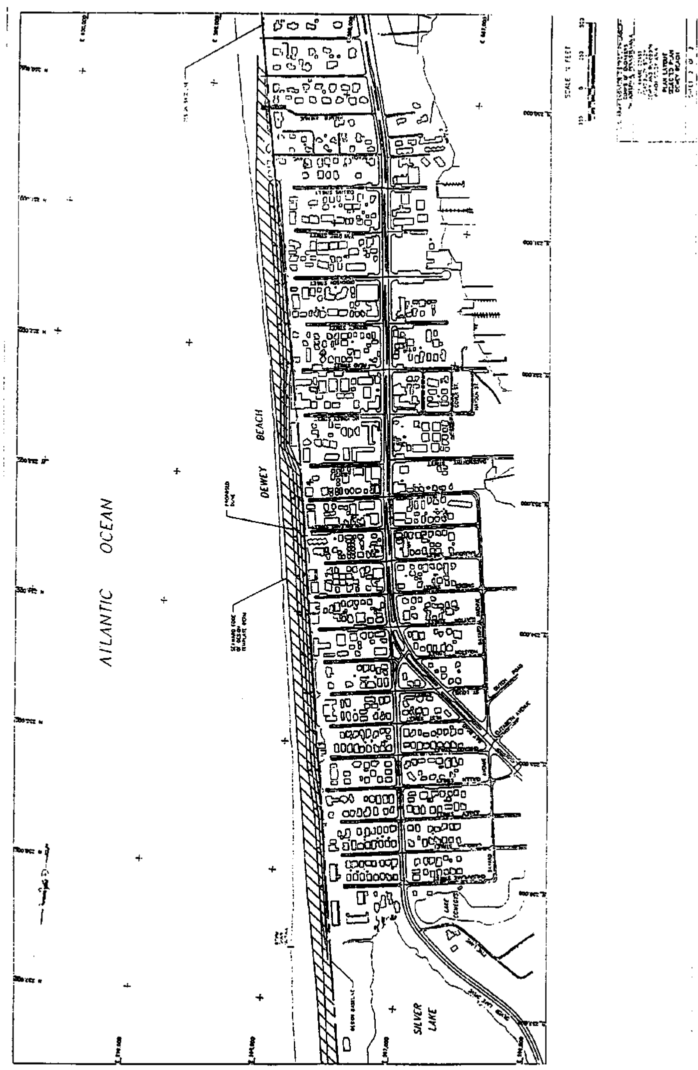
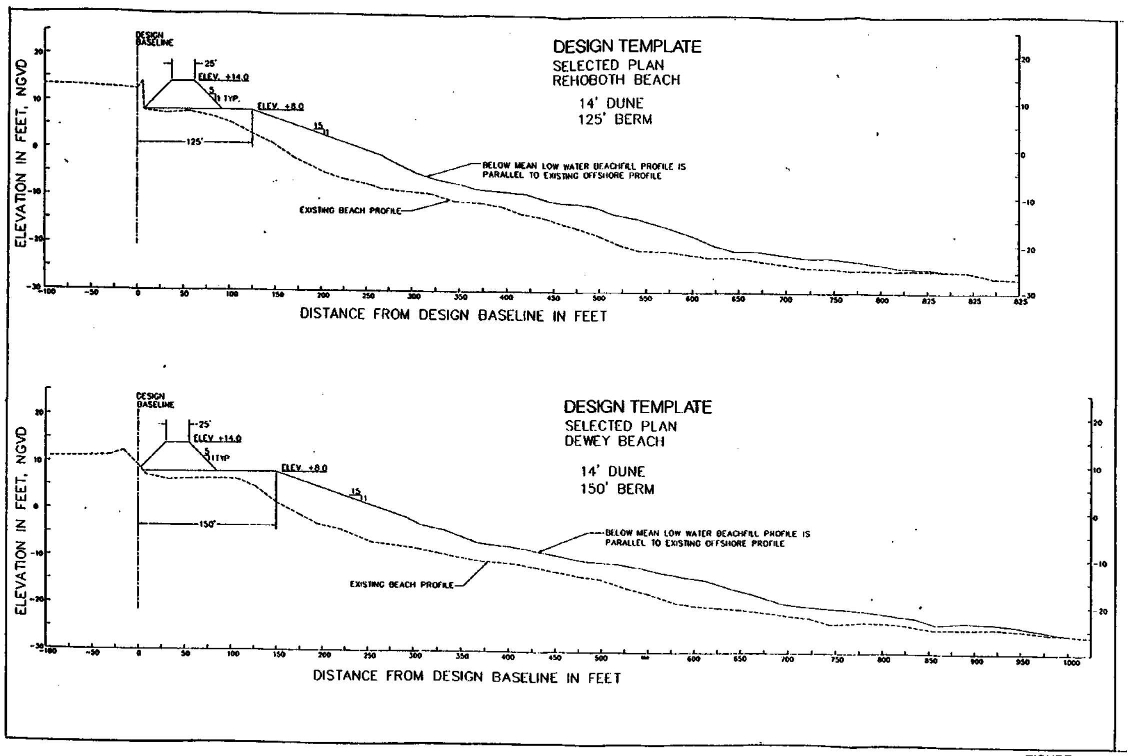


Figure 31



FIGURE

Figure 32

318. A terminal groin is relatively expensive to construct and maintain. This is due to the fact that as the only groin in Dewey Beach, a terminal groin would have no protection from wave action due to storms. In addition, since the predominant net sediment transport is north from North Indian Beach into Dewey Beach, the inclusion of a terminal groin as the terminus of the southern end of the Dewey Beach project would result in sand accumulating on the updrift side (North Indian Beach) while eroding on the down drift side. Since Dewey Beach is on the down drift side of the proposed terminal groin erosion rates would increase along the project area. To compensate for the increased erosion rates, the project would need to include either a larger quantity of initial fill or an increase in the quantity and/or frequency of periodic nourishment. This would greatly increase the cost of the project, while creating spillover benefits for the private community of North Indian Beach. In addition, for significant periods throughout the year sediment transport is in a southerly direction with sand moving from Dewey Beach into North Indian Beach. The resulting erosion on the down drift side of the terminal groin would cause adverse impacts to the private community of North Indian Beach. Construction of a terminal groin was not considered for Rehoboth Beach due to the existence of a groin field.

319. If the proposed project were to include a taper which begins to transition in Dewey Beach and ends the beachfill north of North Indian Beach it would not provide adequate protection for the southern portion of Dewey Beach. In addition, since less fill material would be placed in the southern portion of Dewey Beach, this area would quickly erode, further exposing this area to storm damage. If the southernmost part of Dewey Beach were to be protected only by a transition taper ending at the southern border of Dewey Beach the level of protection in this area would be lower than the rest of the project. Since the southernmost part of Dewey Beach is an erosional "hot spot" the placement of inadequate protection in this area is unacceptable for maintaining the structural integrity of the proposed project. The same argument is relevant for the northern end of the proposed project in Rehoboth Beach.

320. **Optimization of the Nourishment Cycle.** Optimization of the nourishment cycle takes into account the impact on initial construction costs due to change in initial fill quantities. Table 31 provides the annualized costs for the 2 year, 3 year and 4 year nourishment cycle. Based on model results, historical data of shoreline measurements and past experience with shore protection projects, a three year renourishment cycle with a total of 360,000 cubic yards per cycle, is the least cost alternative and is economically justified. Therefore, the three year nourishment cycle is recommended for the Rehoboth Beach/Dewey Beach project.

321. **Dune Seaward of McKinley St., Dewey Beach.** Seaward of McKinley Street are two structures that protrude out onto the beach further than all of the other structures in Dewey Beach. It was determined that because these structures protruded onto the beach, the footprint of the design dune would be too large for the remaining berm. Therefore, in order to provide a continuous dune line along the shorefront of Dewey Beach, a dune at +14 feet NGVD with a top width of 15 feet and slopes of 1V:4H, providing a smaller footprint, was designed for placement seaward of McKinley Street. While the footprint of this dune is smaller than the dune along the rest of Dewey Beach, it allows a continuous line of flood protection along the entire length of Dewey Beach.

TABLE 31 Rehoboth Beach/Dewey Beach Periodic Nourishment Optimization	
Cycle	Average Annual Costs
2 year	$1,753,500
3 year	$1,549,100
4 year	$1,595,200

322. **The Inclusion of the Silver Lake Area.** The transition between the template for Rehoboth Beach and the template for Dewey Beach takes place at Silver Lake which has been designated a Coastal Barrier Resources System (CBRS). Coordination with the U.S. Fish and Wildlife Service indicated that there is no opposition in proposing the inclusion of the Silver Lake with the overall Rehoboth Beach and Dewey Beach project.

323. The extension of the project through the Silver Lake area is necessary to ensure the engineering integrity of the beach restoration project. The inclusion of the Silver Lake area as part of the design template was not to provide direct protection for any structures or potential structures within this CBRS unit, but to provide a continuous minimum beach/dune template through the study area. The proposed project will not promote development in the Silver Lake area. In fact development of the Silver Lake area began prior to the initiation of this feasibility study and is expected to be completed by the base year for the study. Two development companies purchased the land at Sliver Lake and partitioned it into 15 lots. Active marketing to sell these lots and construct houses on them has been ongoing for the past few years. Many of the lots have already been sold and houses have been built on some of them.

324. If the Silver Lake area is excluded from the overall project, the proposed projects for both Rehoboth Beach and Dewey Beach would be subject to flanking due to erosion and wave attack, jeopardizing lands and property in these adjacent areas. It should be noted that the existing conditions of the berm and dune along the Silver Lake area currently meet or exceed the proposed project design template. Therefore, no initial construction efforts are anticipated within the CBRS unit. Beachfill material would only be placed in the Silver Lake area if, in the future, the beach profile were to erode to a condition landward of the design template thereby exposing the adjacent project areas in Rehoboth Beach and Dewey Beach to storm damage. The existing dune system at Silver Lake will be incorporated into the recommended project. To maintain the structural integrity of the dunes, beach access will be controlled by the delineation of dune walkovers with dune fencing and the public will be prohibited from walking on the dune. The result will actually be the enhanced preservation and protection of this valuable habitat.

325. The proposed project is designed to mimic, enhance or restore a natural-like shoreline and does not include any hardened structures. Based on previous coordination (see Appendix D-Pertinent Correspondence) it is felt that the proposed project conforms with the purpose of the Coastal Barrier Resources Act (CBRA) which is to minimize the damage to fish and wildlife and other natural resources associated with coastal barriers.

326. All coordination regarding the CBRA is provided in Appendix D (Pertinent Correspondence) and Appendix G (Public Review Comments). Responses to specific CBRA comments are provided in Appendix G (Public Review Comments).

327. **Beachfill Monitoring Plan.** The project monitoring plan will document beach fill performance and determine conditions within the borrow areas. Periodic assessments will assist in determining renourishment quantities. The program was developed in accordance with EM-1110-2-1004, ER-1110-2-1407, CETN-II-26 and the draft CETN dated 3/13/95 entitled "Recommended Base-level Physical Monitoring of Beach Fills." The following items are to be included in the project monitoring plan: Pre- and post-construction monitoring will consist of beach profile surveys, sediment sampling of the beach and borrow areas, aerial photography, and tidal data collection. The field data collection will be followed up by lab and data analyses. The proposed monitoring program will begin at the initiation of pre-construction efforts and continue throughout the project life. The monitoring program is further described in Appendix A, Section 2.

328. **Operation and Maintenance (O&M).** Coordination has been accomplished with DNREC, the non-Federal sponsor, and they are fully aware of their obligations concerning Operation and Maintenance of the Federal project.

329. Table 32 lists the current expenditures by the State of Delaware for maintenance of the existing dune area. Also included in this table are the estimated expenditures for the proposed project. The incremental difference between what the State is currently spending and what it is estimated to cost to maintain the dune area for the proposed project is considered the true operation and maintenance cost of the proposed project.

330. The annual operation and maintenance of the project includes maintaining the dunes and the dune crossovers (pedestrian access). The dunes will be maintained by shaping the sand with heavy equipment to ensure the presence of the design template. In addition, sand fence, dune walkovers and replanting of dune grass that becomes damaged or suffers deterioration over time will be replaced or maintained as needed. The annual cost for these repairs is estimated to be $37,000 and is based on operation and maintenance experience for similar beachfill projects within the Philadelphia District.

331. **Recreation Benefits.** Incidental recreation benefits are included in the final accounting of total benefits of the selected plan. The towns along the Delaware ocean coast are consistently the number one travel destination in Delaware, and account for half the state's visitations. In 1991, the Delaware Development Office adopted the following tourism policy for the State:

To develop tourism as an industry that contributes to economic growth, while fostering the preservation of natural and cultural resources that improve the quality of life for both the State's citizens and those who travel to Delaware.

TABLE 32
Estimated Operation and Maintenance Costs for the Proposed Rehoboth Beach/Dewey Beach Shore Protection Project

Estimated O&M Costs for the proposed Dewey Beach project

Category	Current Expenditures	Estimated Expenditures	Incremental Difference
Beach Shaping	$20,000	$30,000	$10,000
Dune Grass	$1,000	$1,500	$ 500
Dune Fence	$1,200	$2,000	$ 800
Crossovers	$1,000	$2,000	$ 1,000
		Sub-Total	$12,300

Estimated O&M Costs for the proposed Rehoboth Beach project

Category	Current Expenditures	Estimated Expenditures	Incremental Difference
Beach Shaping	$10,000	$30,000	$20,000
Dune Grass	$0	$1,500	$ 1,500
Dune Fence	$1,200	$2,000	$ 800
Crossovers	$0	$2,000	$ 2,000
		Sub-Total	$24,300
		TOTAL	$36,600
		Say	$37,000

332. It is expected that local and state efforts to attract visitation, and expand their associated facilities, will continue. The Delaware beaches play an extremely significant role in the well being of Delaware's tourism industry and in Delaware's overall economy.

333. A contingent value method survey was completed by the University of Delaware for the Corps of Engineers to determine willingness to pay for the existing beach and an enhanced beach. This is done on a regional basis, encompassing the major beach communities of Rehoboth Beach, Dewey

Beach, Bethany Beach, South Bethany, and Fenwick Island. The work undertaken has two distinct parts. The first part consisted of interviewing recreational beach users at five ocean beach communities during the summer of 1993. The second part of the study involved developing a mail-survey instrument and sending it to 1,004 randomly selected residents within the Mid-Atlantic Region. In total, 910 individuals provided responses through the on-site and mail survey efforts. The entire report is included in Appendix B.

334. Recreation benefits are calculated assuming 100 square feet required per beach user, 97 days in the season with 30% lost to inclement weather, and difference in willingness-to-pay between the without and with-project conditions of $0.67. There is no net increase in capacity between the with and without projects, because the with-project adds a dune with dune grass which does not provide additional recreational beach area. Benefits do not accrue from increased capacity but rather from an increase in recreation experience. Average annual recreation benefits, at October 1995 price levels, in Dewey Beach are $475,000 and $369,000 in Rehoboth Beach.

335. **NED Benefits Summary.** Table 33 presents a summary of the NED benefits associated with the selected plan. Benefits during construction are an additional $30,000.

TABLE 33
AVERAGE ANNUAL NED BENEFITS OF SELECTED PLAN
(October 1995 Price Level)

BENEFIT CATEGORY	WITHOUT PROJECT	WITH PROJECT	ANNUAL BENEFITS
DAMAGES			
STRUCTURE: Erosion	$1,811,000	$ 478,000	$1,333,000
Wave-Inundation	$1,054,000	$ 396,000	$ 658,000
INFRASTRUCTURE	$ 364,000	$ 107,000	$ 257,000
IMPROVED PROPERTY	$ 389,000	$ 137,000	$ 252,000
EMERGENCY COSTS	$ 106,000	$ 33,000	$ 73,000
MAINTENANCE	$ 58,000	$ 29,000	$ 29,000
TOTAL	$3,782,000	$1,180,000	$2,602,000
RECREATION	$5,283,000	$6,127,000	$ 844,000

PROJECT IMPACTS

336. **Impacts to Environmental Resources.** The primary adverse impact of the beach nourishment alternative is the temporary disturbance and destruction of existing benthic resources from dredging at the borrow area and fill placement along the shorefront. Dredging in the borrow area will result in a temporary destruction of the benthic community, however, rapid recolonization is expected to occur within one year from the dredging. Minor shifts in benthic community composition may occur following recolonization. Disturbance to benthic organisms will have minor temporary impacts on food sources for finfish. Beachfill operations along Rehoboth Beach and Dewey Beach will result in temporary degradation of the existing beach habitat during initial construction and the periodic nourishments. Existing benthic organisms on the beach would become buried as a result of the beachfilling operations. Due to the presence of species adapted to high energy and dynamic conditions, recolonization of the beach area is expected to be rapid. The portion of benthic habitat covered by any seaward extension of the beach would represent a long-term loss, however, this would be offset by the creation of similar habitat. The partial burial of the groins in the project area would represent a long-term loss of rocky inter-tidal habitat occupied by aquatic invertebrates that attract birds and fish. Fish and avian utilization of the immediate shoreline area for feeding would be temporarily disrupted, however, they are expected to return immediately after the disturbance. Dredging and the hydraulic placement of beachfill material will result in temporary higher turbidity levels at the borrow site and waters along the shoreline during construction.

337. Depending on the dredging method to be used, it may be necessary to employ sea turtle monitors on the dredges to comply with Section 7 of the Endangered Species Act.

338. Periodic dredging in the borrow area for beach renourishment may affect a potentially recovering surf clam population. The resource agencies will be contacted prior to renourishment cycles in order to determine if monitoring is appropriate.

339. Official comments were received by the U.S. Fish and Wildlife Service pursuant to Section 2(b) of the Fish and Wildlife Coordination Act. All comments and recommendations were given due consideration and were responded to in Appendix G (Public Review Comments).

340. **Impacts to Cultural Resources.** On the basis of the current project plan, the Corps is of the opinion that this project will have no effect on significant cultural resources located in onshore beach and near-shore underwater project areas. These areas are located in a highly unstable and shifting coastal environment where the likelihood for intact and undisturbed cultural resources is considered extremely minimal. The structural remnants buried in front of the "Star of the Sea" building in Rehoboth Beach lack integrity and do not appear to be significant. Documentary review indicates that no historic structures are located in the beach area. Based on these findings, the Corps has not conducted an onshore cultural resource survey. A remote sensing survey was not conducted in the near-shore project area due to unsafe conditions in a very high energy tidal surf zone. Coordination with the Delaware State Historic Preservation Office (DESHPO) for this portion of the proposed project is continuing and will be finalized prior to project construction.

341. The remote sensing investigation of the borrow area identified two relatively small magnetic targets exhibiting shipwreck characteristics that may be associated with one vessel. Proposed sand borrowing activities will adversely impact these target locations, which may represent a significant cultural resource. Therefore, in order to eliminate construction impacts at these locations, the Philadelphia District proposes to completely avoid these two remote sensing targets during sand borrowing operations by delineating at least a 200 foot buffer around each target. The draft report of the remote sensing investigation, entitled *Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island* (Dolan Research, Inc., February, 1994), was submitted to the Delaware State Historic Preservation Office for Section 106 review and comment on February 14, 1994 (Appendix D). In a letter dated December 1, 1994, the DESHPO concurred with the Corps recommendation (see Appendix D).

342. Vibracore samples taken from the borrow area to a depth of 20 feet below the ocean floor indicate a series of shoaled sand deposits with no substantial clay or organic layers indicating buried pleistocene land surfaces. As currently planned, the dredging depth of the borrow area over the life of the project will not exceed this 20 foot depth and, therefore, will have no effect on potentially buried archaeological sites.

343. **Project Cost Estimate.** The estimated first cost for the selected plan described above is $9,114,000 (October 1995 price levels) which includes interest during construction, real estate acquisition costs (including administrative costs), engineering and design (E&D), construction management (CM) and associated contingencies. E&D costs include preparation of plans and specifications, environmental, cultural and coastal pre-construction monitoring and the development and execution of the Project Cooperation Agreement (PCA). A summary of the first cost is shown in Table 34.

344. Periodic nourishment is expected to occur at 3 year intervals subsequent to the completion of initial construction. Based on a volume of 360,000 cubic yards for each nourishment cycle, the total cost per operation, or cycle, is estimated to be $3,638,000 (October 1995 price levels). The total estimated annualized cost of periodic nourishment is $1,071,000 over the 50 year life of the project.

345. The estimated total annualized cost of the selected plan is $1,966,000, which is based on an economic project life of 50 years and an interest rate of 7.625% (October 1995 price levels). This cost includes the annualized first cost, interest during construction, annualized periodic nourishment costs, annualized major rehabilitation costs and post construction monitoring costs.

346. ***Annualized First Costs.*** The duration of construction for the project is estimated to be six months. It is assumed the construction costs would be evenly distributed over the six month period. First costs and, when annualized, total $713,000.

TABLE 34
TOTAL FIRST COST SUMMARY
OCTOBER 1995 PRICE LEVELS

Description of Item	Qty	Unit	Unit Price	Est. Amount	Contingency	Total Amount
Lands and Damages						
Post Authorization Planning	0	0	0	0	0	0
Required Easements Including Surveys Appraisal and Administration	0	Job	LS	$191,680	$23,150	$214,830
Total Lands and Damages				$191,680	$23,150	$214,830
Beach Replenishment						
Mobilization, Demobilization and Preparatory Work		Job	LS	$439,678	$52,762	$492,440
Beachfill	1,437,272	CY	$4.2024	$6,039,992	$905,998	$6,945,990
Dune Grass	91,100	SY	$2.3175	$211,124	$31,669	$242,793
Sand Fence	17,750	LF	$3.0076	$53,385	$8,008	$61,393
Planning, Engineering and Design (PE&D)		Job	LS	$587,970	$88,196	$669,166
Construction Management (S&A)		Job	LS	$417,600	$62,640	$480,240
Total Beach Replenishment				$7,749,749	$1,149,273	$8,892,022
Project Total						
Total Project First Cost				$7,941,429	$1,172,423	$9,113,852
Total Project First Cost (rounded)				**$7,942,000**	**$1,172,000**	**$9,114,000**

347. **Benefits During Construction.** The NED project will be constructed over four months with an additional month before and after construction for mobilization and demobilization. Significant portions of the beach will be fully nourished before the project is completed in its entirety. The portions of the beach nourished early in the construction phase will provide storm damage reduction benefits. The total annualized benefits during construction are $30,000.

348. **Economics of the NED Plan.** With the inclusion of the recreation benefits, the combined project (both reaches) for the study area provides total average annual benefits of $3,476,000 at a total average annual project cost of $1,966,000. Average annual costs include $49,000 in annualized costs for monitoring the project.

349. ***Benefit-Cost Ratio.*** Total average annual benefits and average annual costs are displayed by category in Table 35. The result is a benefit-cost ratio of 1.8 with $1,510,000 in annualized net benefits.

COST APPORTIONMENT

350. The basis for the cost sharing of the protected area will be as follows: total length of the protected area minus the length of the undeveloped reach(es) divided by the total length of the protected area times 65 percent, Federal. All undeveloped privately owned reach(es) will be 100 percent non-Federal. The taper areas will be cost-protected in accordance with the percentage resulted from the protected area, 65% Federal (Table 36).

351. The cost apportionment between Federal and non-Federal total first cost of the selected plan is shown in Table 37. The selected plan has been shown to be economically justified on benefits associated with storm damage reduction. There are no separable recreation features included with this project. Recreation benefits resulting from the selected plan are not required for justification. Therefore, all recreation benefits are assumed to be incidental to the project. In accordance with Section 103 of the Water Resources Development Act of 1986 and appropriate Federal regulations, such as ER 1165-2-130, Federal participation in a project formulated for hurricane and storm damage reduction is 65 percent of the estimated total project first costs, including Lands, Easements, Rights-of-Ways, Relocations and Dredged Material Disposal Areas (LERRD). The estimated market value of LERRD provided by non-Federal interests is included in the total project cost, and they shall receive credit for the value of these contributions against the non-Federal cost share.

352. The cost sharing for the selected plan is based on a total first cost of $9,114,000, and does not include interest during construction, which is used only for economic justification purposes.

353. **Construction and Funding Schedule.** An estimated schedule of expenditures by year is shown in the PMP. A separate Project Management Plan (PMP) describes activities leading to, through and after construction of the selected plan.

TABLE 35 BENEFIT-COST COMPARISON FOR THE NED PLAN	
DISCOUNT RATE	7.625%
PROJECT LIFE	50 YEARS
PRICE LEVEL	OCT. 1995
BASE YEAR	2000
AVERAGE ANNUAL BENEFITS	
STORM DAMAGE REDUCTION	$2,573,000
REDUCED MAINTENANCE	$29,000
RECREATION	$844,000
BENEFITS DURING CONSTRUCTION	$30,000
TOTAL AAB's	$3,476,000
TOTAL PROJECT COSTS	
INITIAL CONSTRUCTION COSTS	$9,114,000
INTEREST DURING CONSTRUCTION*	$196,000
REAL ESTATE COSTS	$215,000
PERIODIC NOURISHMENT (PER CYCLE)	$3,638,000
MAJOR REHABILITATION (ANNUALIZED)	$61,700
OPERATION & MAINTENANCE	$37,000
PROJECT MONITORING (ANNUALIZED)	$49,000
TOTAL AAC's	$1,966,000
BENEFIT TO COST RATIO	1.8
NET BENEFITS	$1,510,000

*Interest During Construction was computed in accordance with procedure contained in paragraph 6-153 of ER 1105-2-100, dated 28 December 1990

TABLE 36
BASIS FOR COST SHARING
THE REHOBOTH BEACH/DEWEY BEACH
SHORE PROTECTION PROJECT

Category	Extent	Purpose	Cost-Sharing (%) Fed	Non-Fed
Federal	0%	N/A	N/A	N/A
Public	100%*	H&SDR**	65%	35%
Private	0%	N/A	N/A	N/A

* The taper areas are being cost shared in accordance with the percentage resulted from the protected area.
** Hurricane and Storm Damage Reduction

TABLE 37
COST SHARING FOR THE SELECTED PLAN
(October 1995 price level)

ITEM	COST
1. INITIAL BEACH REPLENISHMENT	$8,899,000
2. LANDS, EASEMENTS, RIGHTS-OF-WAY, RELOCATIONS, DISPOSAL AREAS (LERRD)	$215,000
3. PERIODIC NOURISHMENT (3 year cycle)	$3,638,000
PROJECT MONITORING (Annualized)	$49,000

PROJECT FEATURE	FEDERAL COST	%	NON-FEDERAL COST	%	TOTAL
Initial Project Costs (Cash Contributions)	$5,924,000		$2,975,000		$8,899,000
LERRD	$0	0%	$215,000	100%	$215,000
Total Initial Project Costs	$5,924,000	65%	$3,190,000	35%	$9,114,000
Periodic Nourishment (50 Years) (includes major replacement costs)	$39,003,000	65%	$21,001,000	35%	$60,004,000
Project Monitoring Costs (50 years)	$1,065,000	65%	$573,000	35%	$1,638,000
Ultimate Project Cost (50 Years)	$45,992,000		$24,764,000		$70,756,000

LOCAL COOPERATION

354. In accordance with Section 105 (a)(1) of WRDA 1986, the Rehoboth Beach/Dewey Beach interim feasibility study was cost shared 50%-50% between the Federal Government and the State of Delaware. The contributed funds of the local sponsor, the Delaware Department of Natural Resources and Environmental Control (DNREC), has shown the intent to support a project for the Rehoboth Beach and Dewey Beach, Delaware.

355. A fully coordinated Project Cooperation Agreement (PCA) package (to include the Sponsor's financing plan) will be prepared subsequent to the approval of the feasibility phase which will reflect the recommendations of this interim feasibility study. The non-Federal sponsor, DNREC, has indicated support of the recommendations presented in this feasibility report and the desire to execute a PCA for the recommended plan. Other non-Federal interests, such as the Town of Rehoboth Beach and the Town of Dewey Beach have indicated their support of the project.

356. In the PCA the non-Federal sponsor will:

- Provide 35 percent of total costs assigned to hurricane and storm damage reduction plus 50 percent of total project costs assigned to recreation, plus 100 percent of total project costs assigned to privately owned shores (where use of such shores is limited to private interests), and as further specified below:

- Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or ensure the performance of all relocations determined by the Federal Government to be necessary for the initial construction, periodic nourishment, operation, and maintenance of the Project.

- Provide all improvements required on lands, easements, and rights-of-way to enable the proper disposal of dredged or excavated material associated with the initial construction, periodic nourishment, operation, and maintenance of the Project. Such improvements may include, but are not necessarily limited to, retaining dikes, waste waters, bulkheads, embankments, monitoring features stilling basins, and dewatering pumps and pipes.

- Provide, during construction, any additional amounts as are necessary to make its total contribution equal to 35 percent of total project costs assigned to hurricane and storm damage reduction plus 50 percent of total costs assigned to recreation, plus 100 percent of total project costs assigned to privately owned shores (where use of such shores is limited to private interests).

- For so long as the Project remains authorized, operate, maintain, repair replace, and rehabilitate the completed Project, or functional portion of the Project, at no cost to the Federal Government, in a manner compatible with the Project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government.

- Give the Federal Government a right to enter, at reasonable manner, upon property that the Non-Federal Sponsor, now or hereafter, owns or controls for access to the Project for the purpose of inspection, and, if necessary after failure to perform by the Non-Federal Sponsor, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the Project. No completion, operation, maintenance, repair, replacement, or rehabilitation by the Federal Government shall operate to relieve the Non-Federal Sponsor of responsibility to meet the Non-Federal Sponsor's obligations, or to preclude the Federal Government from pursuing any other remedy at law or equity to ensure faithful performance.

- Hold and save United States free from all damages arising from the initial construction, periodic nourishment, operation, maintenance, repair, replacement, and rehabilitation of the Project and any Project-related betterments, except for damages due to the fault or negligence of the United States or its contractors.

- Keep, and maintain books, records, and other evidence pertaining to costs and expenses incurred pursuant to the Project in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20.

- Perform, or cause to be performed, any investigations for hazardous substances as are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law (PL) 96-510, as amended, 42 U.S.C. 9601-9675, that may exist in, on, or, under lands, easements, or rights-of-way that the Federal Government determines to be required for the initial construction, periodic nourishment, operation, and maintenance of the Project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the Non-Federal Sponsor with prior specific written direction, in which case the Non-Federal Sponsor shall perform such investigations in accordance with such written direction.

- Assume complete financial responsibility, as between the Federal Government and the Non-Federal Sponsor for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the initial construction, periodic nourishment, operation, or maintenance of the Project.

- As between the Federal Government and the Non-Federal Sponsor, the Non-Federal Sponsor shall be considered the operator of the Project for the purpose of CERCLA liability. To the maximum extent practicable, operate, maintain, repair, replace and rehabilitate the Project in a manner that will not cause liability to arise under CERCLA.

- Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1957 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way, required for the initial construction, periodic nourishment, operation, and maintenance of the Project, including those necessary for relocations, borrow material, and dredged or excavated material disposal, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act.

- Comply with all applicable Federal and State laws and regulations, including, but not limited to, Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army".

- Provide 35 percent of that portion of total historic preservation mitigation and data recovery costs attributable to hurricane and storm damage reduction that are in excess of one percent of the total amount authorized to be appropriated for hurricane and storm damage reduction.

- Provide 50 percent of that portion of total historic preservation mitigation and data recovery costs attributable to recreation that are in excess of one percent of the total amount authorized to be appropriated for recreation.

- Provide 100 percent of that portion of total historic preservation mitigation and data recovery costs attributable to privately owned shores (where use of such shores is limited to private interests) that are in excess of one percent of the total amount authorized to be appropriated for privately owned shores (where use of such shores is limited to private interests).

- Participate in and comply with applicable Federal flood plain management and flood insurance programs.

- Not less than once each year inform affected interests of the extent of protection afforded by the Project.

- Publicize flood plain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in preventing unwise future development in the flood plain and in adopting such regulations as may be necessary to prevent unwise future development and to ensure compatibility with the protection provided by the Project.

- For so long as the project remains authorized, the Non-Federal Sponsor shall ensure continued conditions of public ownership and use of the shore upon which the amount of

Federal participation is based.

- Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

357. The Towns of Rehoboth Beach and Dewey Beach have expressed strong support for a potential project. The cooperation between the various governments indicate a strong willingness to proceed with a potential solution to the storm damage problems facing the Towns of Rehoboth Beach and Dewey Beach. In addition to the annual budget request for beach preservation/capital improvement funds, to show their commitment to the project and to raise additional funds the State of Delaware has imposed a rental tax on hotel and motel rooms, with the proceeds to go to coastal storm damage reduction projects. On the local level, the town of Dewey Beach has installed a measure to assess properties within the town limits with the resulting funds dedicated to beach preservation efforts.

358. In an effort to keep the Sponsor informed of study progress, close coordination through telephone conversations, formal and informal meetings continued throughout the feasibility phase. In addition, newsletters were distributed through general mailings describing the ongoing feasibility study efforts.

359. Coordination efforts shall continue through the authorization phase remain constant, including coordination of this report with other State and Federal agencies. It is currently anticipated that a public meeting will be held upon approval of this feasibility report.

Final
Environmental Impact Statement
Delaware Coast from Cape Henlopen to Fenwick Island
Feasibility Study
Rehoboth Beach/Dewey Beach Interim Feasibility Study
Sussex County, Delaware

June 1996

PREPARED BY:
UNITED STATES ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT
PLANNING DIVISION
ENVIRONMENTAL RESOURCES BRANCH
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PHILADELPHIA, PA 19107-3390

Final
Environmental Impact Statement
Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study
Rehoboth Beach and Dewey Beach Project
Sussex County, Delaware

The responsible lead agency is the U.S. Army Corps of Engineers, Philadelphia District.

Abstract:

This study evaluates existing conditions and shore protection problems facing Dewey Beach and Rehoboth Beach along the Atlantic Coast of Delaware. Rehoboth Beach and Dewey Beach are extensively developed shore communities in Delaware, which play a principal role in the well being of Delaware's tourism industry. Significant beach and dune erosion has left these communities vulnerable to storm damages and with reduced recreational opportunities. Severe storms in recent years have caused a reduction in the overall beach height and width along the study area, which, along with the absence of suitable dunes, exposes the towns of Rehoboth Beach and Dewey Beach to catastrophic damage from ocean flooding and wave attack.

After evaluating several structural and non-structural storm damage reduction alternatives, the recommended plan was determined to be beach nourishment utilizing sand obtained from a borrow source on Hen and Chickens Shoal. Beach nourishment will consist of berm and dune restoration in Rehoboth Beach and Dewey Beach. This plan would require placement of approximately 1.43 million cubic yards of sand for initial construction with 360,000 cubic yards anticipated for periodic nourishments every 3 years over the 50 year project life. The proposed beach nourishment plan includes placing fill along approximately 13,500 linear feet of beach extending from the northern end of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach. The project would taper into the existing shoreline, in the north end at Deauville Beach and in the south end at North Indian/Indian Beach. The proposed beach nourishment would result in a 125 foot wide berm at an elevation of +8 feet NGVD in Rehoboth Beach and a 150 foot wide berm at an elevation of +8 feet NGVD in Dewey Beach. A dune is proposed along the entire length and on top of the berms in both communities with a top elevation of +14 feet NGVD and a top width of 25 feet. The dune is proposed to be planted with dune grass, and would also contain 16,400 linear feet of sand fence, delineated walkovers, and vehicle access ramps. Beach nourishment operations would impact approximately 136 acres below mean high water, which includes approximately 11 acres of marine intertidal habitat. The proposed sand source is a 1,120 acre offshore borrow area located on the southern portion of Hen and Chickens Shoal.

A Section 404 (b)(1) evaluation has been prepared and is included in the Final Environmental Impact Statement. This evaluation concludes that the proposed action would not result in any significant environmental impacts relative to the areas of concern under Section 404 of the Federal Clean Water Act.

PLEASE SEND YOUR COMMENTS TO
THE DISTRICT ENGINEER BY:

For further information on this statement, please contact:
Steve Allen
Environmental Resources Branch,
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Wanamaker Building, 100 Penn Square East
Philadelphia, Pennsylvania 19107-3390

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1.0 SUMMARY

1.1 PURPOSE AND NEED

The purpose of this statement is to evaluate the anticipated environmental impacts of the alternatives developed for the storm damage reduction at Dewey Beach and Rehoboth Beach, Sussex County, Delaware.

The need to which the U.S. Army Corps of Engineers, Philadelphia District is responding is based on the need to reduce the potential for storm damage to the structures and property associated with the communities of Rehoboth Beach and Dewey Beach, Delaware.

The principal source of economic damages identified in Rehoboth Beach and Dewey Beach are storms. Severe storms in recent years have caused a reduction in the overall beach height and width along the study area, and deterioration of the three northernmost locally constructed groins. This as well as the absence of significant dunes exposes the towns of Rehoboth Beach and Dewey Beach to catastrophic damage from ocean flooding and wave attack.

1.2 BACKGROUND

The project location (Figure 1-1) is a segment of Atlantic Coast beach in Sussex County, Delaware that extends from Indian Beach on the south through the communities of Dewey Beach and Rehoboth Beach, and tapers into Deauville at the northern terminus. The communities of Dewey Beach and Rehoboth Beach are Delaware's prime shore recreational areas. The beaches along with the boardwalk in Rehoboth Beach are among the main attractions of the area. It is this beach which has been subject to erosion by storms and wave action. Within this area, structural damage has occurred through direct wave action, particularly at those locations where at times there is virtually no remaining beach to protect the structures lining the shore.

Efforts have been made to remedy the problem of beach loss within the project area since the early 1900's. These have included both numerous studies and actual construction. A total of 25 stone and timber groins were constructed in the area between Rehoboth Beach and Bethany Beach by the State during the period between 1962 and 1964. Nine of these groins are present within the Dewey Beach and Rehoboth Beach project area.

In 1957, 1961, and 1963 approximately 1,040,000 cubic yards of sand was placed on the beach between Rehoboth Beach and Indian River Inlet under the authorization of a report submitted to Congress by the Secretary of the Army on 14 June 1957, and

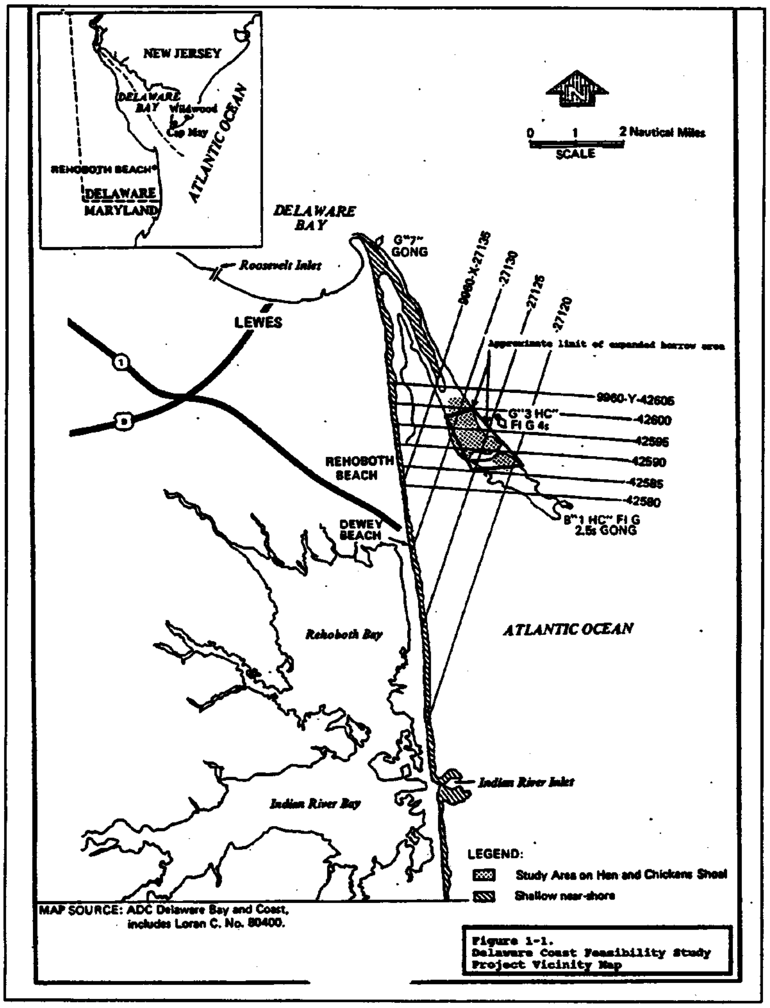


Figure 1-1.
Delaware Coast Feasibility Study
Project Vicinity Map

printed in House Document No. 216, 85th Congress, 1st Session, and the River and Harbor Act of 1958. The material placed on the beaches during the period between 1957 and 1961 was substantially lost during the coastal storm of March 1962. Emergency work to restore the beaches and the construction of the dune was undertaken by the Federal Government and was completed by September 1962.

When the Rehoboth Beach/Dewey Beach Interim Feasibility Study was initiated in 1992, investigations into the existing condition determined that the berm and dune profile was in a significantly degraded condition along the study area. Over the next two years further erosion had exposed the Town of Dewey Beach to potentially significant damage from coastal storms. By the summer of 1994 the State of Delaware, in cooperation with the Town of Dewey Beach, determined that conditions along the shoreline of Dewey Beach warranted the placement of emergency beachfill to provide protection against coastal storms. As a result approximately 600,000 cubic yards of sand (obtained from the southern portion of Hen and Chickens Shoal) was placed along the shoreline of Dewey Beach to build up the berm and to construct a dune along the southern third of town. Since the Interim Feasibility Study was initiated prior to the State's emergency beachfill project in the summer of 1994, the Study does not take into account the existing improved condition along the shoreline of Dewey Beach. However, analyses of the with-out project condition determined that, by the base year for construction (2000), continuous erosion in Dewey Beach will cause the berm and dune profile to approximate the existing condition prior to the placement of the emergency beachfill material.

1.3 ALTERNATIVES

A number of structural and non-structural storm damage reduction alternatives were identified and evaluated individually and in combination on the basis of their suitability, applicability and merit in meeting the planning objectives, planning constraints, economic criteria, environmental criteria and social criteria for the study. The following paragraphs describe several of the alternatives considered, however, a more detailed analysis of the alternatives screening is presented in the main report on pages 81-128.

The screening concluded that only beach nourishment utilizing material dredged from a nearby source should be considered further. The details of the preferred plan, the beach nourishment alternative are as follows: Beach nourishment will consist of berm and dune restoration in Dewey Beach and Rehoboth Beach. This plan will require approximately 1.43 million cubic yards of sand for initial beachfill placement with approximately 360,000 cubic yards for periodic renourishment every 3 years over a 50 year project life. The proposed sand source is a 1,120 acre area on the southern portion of Hen and Chickens Shoal. The proposed beach nourishment plan includes approximately 13,500 linear feet of beachfill extending from the northern end of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach. The selected plan tapers into the existing shoreline in the north end at Deauville and in the southern end at North Indian Beach. The proposed beach nourishment will result in a 125 foot wide berm at an elevation of +8 feet NGVD in Rehoboth Beach and a 150 foot wide berm at an elevation of +8 feet NGVD in Dewey Beach. A dune is proposed along the entire length and on top of the berms in both communities with a top elevation of +14 feet NGVD and a top width of 25 feet. The dune is proposed to be planted with 17.5 acres of dune grass. The dune will also contain approximately 16,400 linear feet of sand fence and delineating walkovers and vehicle access ramps.

1.4 MAJOR CONCLUSIONS AND FINDINGS

Beach nourishment represents the least environmentally damaging structural method of reducing potential storm damages at a reasonable cost and in a way that is both socially acceptable and yet is feasible and proven to work in high energy environments. The somewhat transient nature of beach nourishment is actually advantageous because the beach fill is capable of being dynamic and adjusting to changing conditions until equilibrium can again be achieved. Despite being structurally flexible, the created beach can effectively dissipate high storm energies although at its own expense. Costly rigid structures like seawalls and breakwaters utilize massive amounts of material foreign to the existing environment to absorb the force of the waves. Beach nourishment uses material typical of the adjacent areas, sand, to buffer the shoreline structures against storm damage. Consequently beach nourishment is aesthetically more pleasing as it represents the smallest departure from the existing conditions in a visual and physical sense unlike groins. When the protective beach is totally dispersed by the wave action, the original beach remains. On the other hand, bulkheads, seawalls, and revetments may lead instead to eventual loss of beach as the end of their project life is approached.

Some of the suggested non-structural storm damage reduction alternatives are currently being practiced, such as flood insurance and development regulation. Consequently, implementation is somewhat of a moot point. Others such as land acquisition are prohibitively expensive and are socially unacceptable in any event.

1.5 AREAS OF CONCERN

A project of this nature will have temporary adverse impacts on water quality and aquatic organisms. Dredging will increase suspended solids and turbidity at the point of dredging and at the discharge (beachfill) site. The area to be dredged and the area where the material will be deposited will be subject to extreme disturbance. Many of the benthic organisms will become smothered at the beachfill site. Dredging will result in the temporary complete loss of the benthic community in the borrow area. These disruptions are expected to be of short-duration and of minor significance. Rapid recolonization of the borrow site by benthic organisms is expected to occur after dredging ceases (Saloman et al. 1982, Cutler et al., 1982, Hurme et al. 1988). Dredging will consequently temporarily displace a food source for most finfish. The borrow area was historically a productive surfclam (Spisula solidissima) fishery, however; currently, there are no commercially viable densities along the Delaware Coast. Periodic maintenance disturbances subsequent to the initial dredging may have adverse effects on any potential recovery of the surfclam fishery.

Concerns regarding the use of a hopper dredge and its potential impact on Federally listed threatened and endangered sea turtles were raised with respect to this project. A Biological Assessment that discusses Philadelphia District hopper dredging activities and potential effects on Federally threatened or endangered species of sea turtles has been prepared, and was formally submitted to the National Marine Fisheries Service in accordance with Section 7 of the Endangered Species Act. It is anticipated that NMFS will issue a Biological Opinion prior to preparation of the Final Environmental Impact Statement. Adherence to the findings of the Biological Opinion will insure compliance with Section 7 of the Endangered Species Act. In the interim, measures to reduce the likelihood of disturbing or taking of these species would be implemented for all Philadelphia District Corps of Engineers dredging activities when there is reason to believe that sea turtles and other marine life may be potentially impacted. These measures are further discussed on page 5-16.

Concern over the impacts of a beachfill operation on the State and Federal threatened piping plover was raised. There has been no recent nesting incidences within the project impact area. However, should a nesting pair(s) appear within the project impact area prior to or during the initial beachfill and subsequent periodic beach nourishments, appropriate measures to avoid adversely impacting these birds will be implemented. Mitigative measures will be coordinated with the U.S. Fish and Wildlife Service and the Delaware Division of Fish and Wildlife. These measures may include the establishment of buffer zones around discovered nests and conducting beachfill operations around the buffer zone until nesting is completed.

1.6 ENVIRONMENTAL STATUTES AND REQUIREMENTS

Preparation of this Final Environmental Impact Statement (FEIS) has included several coordination/scoping meetings with appropriate Federal and State resource agencies. After public review of the Draft EIS, a Water Quality Certificate, in accordance with Section 401 of the Clean Water Act, and a concurrence of Federal consistency with the Delaware Coastal Zone Management Program, in accordance with Section 307© of the Coastal Zone Management Act, was obtained from the Delaware Department of Natural Resources and Environmental Control (DNREC). A Section 404(b)(1) evaluation has been prepared and is included as Section 8.0 of the FEIS. This evaluation concludes that the proposed action would not result in any significant environmental impacts relative to the areas of concern under Section 404 of the Clean Water Act. In accordance with the Fish and Wildlife Coordination Act (FWCA), a planning aid report was obtained and is provided in the pertinent correspondence section of the main report. A section 2(b) FWCA report was obtained after circulation of the Draft EIS and the comments presented in that report were given due consideration in the preparation of the FEIS. A copy of the 2(b) FWCA report and corresponding comments is presented in the comment/response section. Coordination with the U.S. Fish and Wildlife Service has been conducted regarding compliance with the Coastal Barrier Resources Act, and is addressed in paragraph 1.6.1 of the FEIS, pertinent correspondence (Appendix D), and DEIS comment/response section.

Compliance will be met for all environmental quality statutes and environmental review requirements with distribution of the Final Environmental Impact Statement (FEIS). Table 1-1 provides a list of Federal environmental quality statutes applicable to this statement, and their compliance status relative to the current stage of project review.

1.6.1 Coastal Barrier Resources Act

The transition between the template for Rehoboth Beach and the template for Dewey Beach takes place at Silver Lake which has been designated for inclusion in the Coastal Barrier Resources System (CBRS). This involves a small portion of beach (0.15 miles in length) between Rehoboth Beach and Dewey Beach adjacent to Silver Lake (Figure 1-2). Lands included in the CBRS are designated by the Coastal Barrier Resources Act (CBRA), which restricts Federal expenditures that may have the effect of encouraging development of coastal barriers. The CBRA allows Federal expenditures for "nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore natural stabilization systems provided they are consistent with the purposes of the Act". Based on these provisions and the proposed design, the proposed berm and dune restoration was

Compliance with Environmental Quality Protection
Statutes and Other Environmental Review Requirements

Federal Statutes	Compliance w/Proposed Plan
Archeological - Resources Protection Act of 1979, as amended	Full
Clean Air Act, as amended	Full
Clean Water Act of 1977	Full
Coastal Barrier Resources Act	Full
Coastal Zone Management Act of 1972, as amended	Full
Endangered Species Act of 1973, as amended	Full
Estuary Protection Act	Full
Federal Water Project Recreation Act, as amended	N/A
Fish and Wildlife Coordination Act	Full
Land and Water Conservation Fund Act, as amended	N/A
Marine Protection, Research and Sanctuaries Act	Full
National Historic Preservation Act of 1966, as amended	Full
National Environmental Policy Act, as amended	Full
Rivers and Harbor Act	Full
Watershed Protection and Flood Prevention Act	N/A
Wild and Scenic River Act	N/A
<u>Executive Orders, Memorandum, etc.</u>	
EO 11988, Floodplain Management	Full
EO 11990, Protection of Wetlands	Full
EO 12114 Environmental Effects of Major Federal Actions	Full

Full Compliance - Requirements of the statute, EO, or other environmental requirements are met for the current stage of review.
Partial Compliance - Some requirements of the statute, E.O., or other policy and related regulations remain to be met.
Noncompliance - None of the requirements of the statute, E.O., or other policy and related regulations have been met.
N/A - Statute, E.O. or other policy and related regulations are not applicable already been sold and houses have been built on some of them.

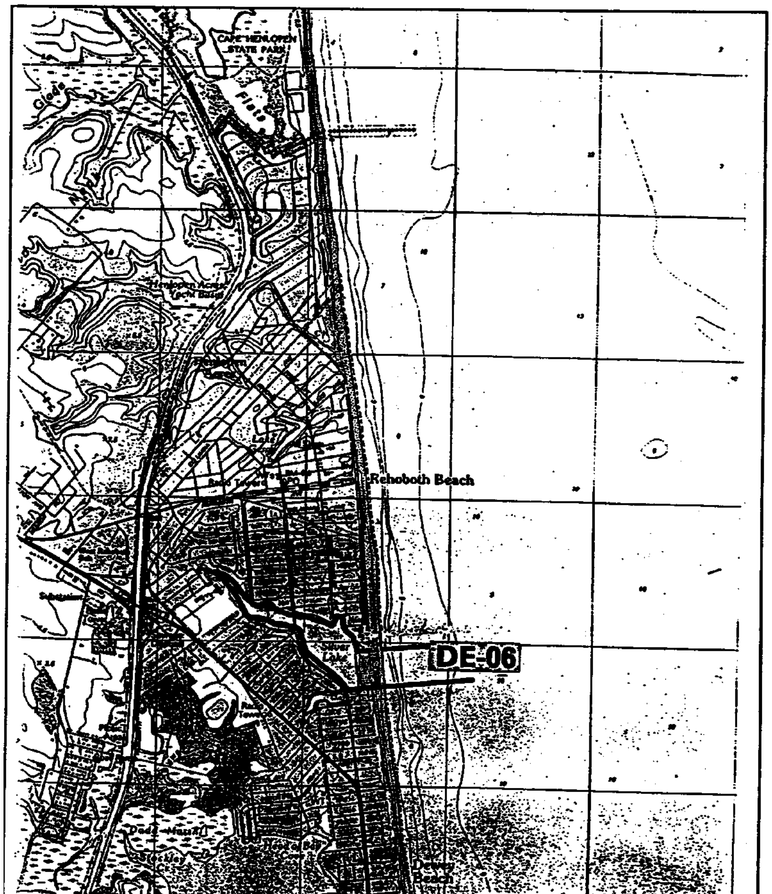


Figure 1-2.
Delaware Coast Feasibility Study
Silver Lake Coastal Barrier
Resources System (CBRS) Unit

determined to be consistent, and in compliance with the CBRA.

The extension of the project through the Silver Lake area is necessary to ensure the engineering integrity of the beach restoration project. The inclusion of the Silver Lake area as part of the design template was not to provide direct protection for any structures or potential structures within this CBRS unit, but to provide a continuous minimum beach/dune template through the study area. The proposed project will not promote development in the Silver Lake area. Development of the Silver Lake area began prior to the initiation of this feasibility study and is expected to continue into the future regardless of the presence of a Corps project. Two development companies purchased the land at Sliver Lake and partitioned it into 15 lots. Active marketing to sell these lots and construct houses on them has been ongoing for the past few years. Many of the lots have Table 1-1.

If the Silver Lake area is excluded from the overall project, the proposed projects for both Rehoboth Beach and Dewey Beach would be subject to flanking due to erosion and wave attack, jeopardizing lands and property in these adjacent areas. It should be noted that the existing conditions of the berm and dune along the Silver Lake area currently meet or exceed the proposed project design template. Therefore, no initial construction efforts are anticipated within the CBRS unit. Beachfill material would only be placed in the Silver Lake area if, in the future, the beach profile were to erode to a condition landward of the design template thereby exposing the adjacent project areas in Rehoboth Beach and Dewey Beach to storm damage. The existing dune system at Silver Lake will be incorporated into the recommended project. To maintain the structural integrity of the dunes, beach access will be controlled by the delineation of dune walkovers with dune fencing and the public will be prohibited from walking on the dune. The result will actually be the enhanced preservation and protection of this valuable habitat.

The proposed project is designed to mimic, enhance or restore a natural-like shoreline and does not include any hardened structures. Based on previous coordination (see Appendix D- Pertinent Correspondence) it is felt that the proposed project conforms with the purpose of the Coastal Barrier Resources Act (CBRA) which is to minimize the damage to fish and wildlife and other natural resources associated with coastal barriers.

2.0 NEED FOR AND OBJECTIVE OF ACTION

2.1 NEED

The proposed action is based on a need for storm damage reduction, which benefits the communities of Rehoboth Beach and Dewey Beach. The need for storm damage reduction action is based on storm damage vulnerability with a high potential for storm-induced erosion, inundation and wave attack, which is exacerbated by long term shoreline erosion.

The ground elevation of Rehoboth Beach and Dewey Beach decreases from +22 feet NGVD in the northern part of Rehoboth Beach to + 10 feet NGVD in the southern part of Dewey Beach. Although some areas have dunes, the ocean shoreline consists predominantly of a continuous strip of low lying beach with a series of 9 groins along the oceanfront in Rehoboth Beach and one groin in Dewey Beach.

The principal source of economic damages identified in Rehoboth Beach and Dewey Beach are storms. Severe storms in recent years have caused a reduction in the overall beach height and width along the study area, and deterioration of the three northernmost locally constructed groins. This as well as the absence of significant dunes exposes the towns of Rehoboth Beach and Dewey Beach to catastrophic damage from ocean flooding and wave attack.

In recent years the erosion problems have become more critical as several coastal storms have buffeted the Atlantic coast of Delaware. Since the March 1962 storm which caused, in 1962 dollars, $16.7 million in damages, the most notable storms have occurred in December 1974, October 1977, March 1984, September 1984, October 1991, January 1992 and December 1992. It should be noted that the January 1992 and December 1992 storms resulted in the President of the United States declaring Sussex County, DE, which includes the entire Atlantic Ocean coast of Delaware, a National Disaster Area.

Progressive and constant erosion is evident in certain areas of the coastline (Table 2-1). Historically, recorded beach erosion has existed in Delaware since 1843, though according to Goodman (1973), it was not a significant problem until the 1950's when tourism, and hence development, increased, and the economic impact of beach erosion became apparent. Local interests constructed groins between 1922 and 1964 indicating that beach erosion was in fact a problem prior to 1950. Efforts undertaken to minimize losses associated with storm damage include building code improvements and building restrictions. Many portions of the developed coast will remain vulnerable however, due to the proximity of structures to the beach and the level of development.

Table 2-1. Predicted Erosion Rates at Rehoboth Beach and Dewey Beach, Delaware.

Reach	Length (feet)	Range of Shoreline Change Rate* (feet/year)	Average (feet/year)
Rehoboth Beach	8500	+3 to -10	-1
Dewey Beach	5400	+3 to -5	-3

* Negative values represent erosion; positive values represent accretion

It should be noted that simply because an area may exhibit relative stability or low background erosion rates that the need to fully address options for additional shore protection is not perceived. As mentioned earlier, in the case of Rehoboth Beach, which lost a great deal of beach elevation during the recent storms, much of the existing beachfront lacks an adequate dune system.

When the Rehoboth Beach/Dewey Beach Interim Feasibility Study was initiated in 1992, investigations into the existing condition determined that the berm and dune profile was in a significantly degraded condition along the study area. Over the next two years further erosion had exposed the Town of Dewey Beach to potentially significant damage from coastal storms. By the summer of 1994 the State of Delaware, in cooperation with the Town of Dewey Beach, determined that conditions along the shoreline of Dewey Beach warranted the placement of emergency beachfill to provide protection against coastal storms. As a result approximately 600,000 cubic yards of sand (obtained from the southern portion of Hen and Chickens Shoal) was placed along the shoreline of Dewey Beach to build up the berm and to construct a dune along the southern third of town. Therefore, the existing state of the berm and dune has been altered from what is stated in the main report. However, analyses of the with-out project condition determined that, by the base year for the study, continuous erosion in Dewey Beach will cause the berm and dune profile to approximate the existing condition prior to the placement of the emergency beachfill material.

When the Rehoboth Beach/Dewey Beach Interim Feasibility Study was initiated in 1992, investigations into the existing condition determined that the berm and dune profile was in a significantly degraded condition along the study area. Over the next two years further erosion had exposed the Town of Dewey Beach to potentially significant damage from coastal storms. By the summer of 1994 the State of Delaware, in cooperation with the Town of Dewey Beach, determined that conditions along the

shoreline of Dewey Beach warranted the placement of emergency beachfill to provide protection against coastal storms. As a result approximately 600,000 cubic yards of sand (obtained from the southern portion of Hen and Chickens Shoal) was placed along the shoreline of Dewey Beach to build up the berm and to construct a dune along the southern third of town. Since the Interim Feasibility Study was initiated prior to the State's emergency beachfill project in the summer of 1994, the Study does not take into account the existing improved condition along the shoreline of Dewey Beach. However, analyses of the with-out project condition determined that, by the base year for construction (2000), continuous erosion in Dewey Beach will cause the berm and dune profile to approximate the existing condition prior to the placement of the emergency beachfill material.

Over the years, erosion has seriously reduced the ability of the shoreline in the project area to provide adequate storm damage protection for the towns of Rehoboth Beach and Dewey Beach. Continuation of this historic trend will increase the potential for economic losses and the threat to human life and safety.

2.2 OBJECTIVES

Planning objectives were identified based on problems, needs and opportunities as well as existing physical and environmental conditions present in the project area.

In general, the prime Federal objective is to contribute to the National Economic Development (NED) account consistent with protecting the Nation's environment. Both of these objectives must be consistent with national legal statutes, applicable executive orders, and other Federal planning requirements. The general and specific planning objectives for the Rehoboth Beach/Dewey Beach Interim Feasibility Study take an integrated systematic approach to the solution of the erosion and inundation problems associated with coastal storms in the towns of Rehoboth Beach and Dewey Beach. Accordingly, the following general and specific objectives have been identified:

General:

- Meet the specified needs and concerns of the general public.
- Respond to expressed public desires and preferences.
- Be flexible to accommodate changing economic, social and environmental patterns and changing technologies.
- Integrate with and be complementary to other related programs in the study area.

- Be implementable with respect to financial and institutional capabilities and public support.

Specific:

- Reduce the threat of potential future damages due to the effects of storms, with an emphasis on inundation and recession of the shoreline.
- Mitigate the effect of, or prevent, the long-term erosion that is now being experienced.
- In accordance with the limits of institutional participation, all plan components must maximize NED (National Economic Development) benefits.
- Enhance the recreational potential of the area.
- Where possible, preserve and maintain the environmental character of the areas under study, including such considerations as aesthetic, environmental and social concerns, as directly related to plans formulated for implementation by the Corps.

2.3 PROJECT AUTHORITY

The Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study is being conducted in response to a resolution adopted by the U. S. Senate Committee on Environment and Public Works dated 23 June 1988. This resolution reads as follows:

> "RESOLVED BY THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS OF THE UNITED STATES SENATE, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby requested to review the report on the Delaware Coast from Kitts Hummock to Fenwick Island, Delaware, published as House Document Number 85-216, and other reports, with a view to determining the advisability of providing improvements in the interest of beach erosion control, hurricane protection, and related purposes, along the Delaware Coast from Cape Henlopen to Fenwick Island. Included in this study will be the development of a physical and engineering data base on coastal area changes and processes, including appropriate monitoring during development of the data base, as the basis for actions to prevent the harmful effects of shoreline erosion and storm damage."

2.4 PUBLIC CONCERNS

Initial discussions with local, State, and Federal agencies produced several concerns that were either environmental or socio-economic in nature.

The non-Federal sponsor for this feasibility study is the Delaware Department of Natural Resources and Environmental Control (DNREC). Currently, DNREC's concern, within the scope of this interim feasibility study, is with shore protection problems at Rehoboth Beach and Dewey Beach. The State is interested in a long term Federal shore protection project due to funding constraints which prohibit the State and local governments from carrying out a long term shore protection program on their own.

Siting of a sand borrow area was a primary environmental concern raised for this project. Issues involved with borrow area selection included the presence/absence of significant cultural resources, benthic resources, fisheries impacts, threatened and endangered species, water quality impacts, and sand grain size compatibilities with beach material. Some of these issues required further investigation.

3.0 ALTERNATIVES

3.1 PRELIMINARY SCREENING OF ALTERNATIVES

A number of structural and non-structural storm damage reduction alternatives were identified and evaluated individually and in combination on the basis of their suitability, applicability and merit in meeting the planning objectives, planning constraints, economic criteria, environmental criteria and social cirteria for the study. The following paragraphs describe several of the alternatives considered, however, a more detailed analysis of the alternatives screening is presented in the main report on pages 81-128.

3.1.1 Structural Storm Damage Reduction Alternatives

3.1.1.1 Bulkheads

Sections of Rehoboth Beach and Dewey Beach already contain bulkheads along the shoreline. There are seven timber bulkheads in Dewey Beach totaling 1,750 feet in length, and there are five bulkheads in Rehoboth Beach totaling 1,150 feet in length. The majority of the bulkheads are constructed of timber pile and sheeting, except for one bulkhead in Rehoboth Beach at Surf and Lake Ave, which is constructed of steel sheetpile. The bulkheads in Dewey Beach are privately constructed, fronting one or two structures. The bulkheads in Rehoboth Beach are fewer and for the most part were constructed by the City of Rehoboth Beach at or near the street ends. The bulkheads serve the purpose of stabilizing the upland behind them, as well as protecting the upland against wave action. Bulkheads can be characterized as an erosion control measure not designed to stand up to direct wave attack in ocean exposed locations. They do not provide a long term solution, because a more substantial wall is required as the beach continues to recede and larger waves reach the structure. In addition, vertical bulkheads can suffer from severe scouring when toe protection is not provided.

3.1.1.2 Seawalls

These structures are similar in nature and construction to bulkheads and revetments, though typically more massive. Unlike bulkheads, seawalls are designed to withstand direct wave attack and to dissipate or deflect the wave energy. Seawalls provide more substantial erosion and storm protection than bulkheads in case of severe erosion of the beach. Costs of constructing a seawall, however, could be prohibitively high, with values of thousands of dollars per linear foot. Construction of a seawall without a periodic beach nourishment program creates the potential for impairing natural sediment transport processes, which in turn can result in narrowing and deepening of the downdrift beaches in the vicinity of the seawall. This is an undesirable feature at Rehoboth Beach and Dewey Beach, where beach use is extremely important. Moreover, an extensive seawall would create an artificial appearance which may be objectionable to beach users as well as local residents.

3.1.1.3 Revetments

Revetments are also similar in nature and construction to seawalls, however, they are typically sloped structures along a beach, dune, or bluff. Revetments, like seawalls, are designed to stand up to and dissipate wave energy. Revetments depend on the underlying soil for support; therefore, there is a vulnerability to damage and failure due to undermining. In addition, they typically cover an extensive beach area, which is not a desirable feature considering the amount of recreational beach use at both Rehoboth Beach and Dewey Beach.

3.1.1.4 Offshore Breakwater

Breakwaters have the effect of reducing wave action and acting as a littoral barrier that tends to build the shoreline leeward of them. Offshore breakwaters can range from floating tire or inflated structures placed in shallow water, to massive stone structures founded in relatively deep water. Particular care must be taken in the design and location of the structure as erosion of the downdrift beach can occur if the structure is placed too near the shore, thus cutting off some of the littoral drift. Gaps or breaks in the structure must also be permitted to prevent the development of undesirable hydraulic currents between the ends of the structures, and to maintain water quality inshore of the structure. To be of material benefit, such a structure would have to be as long as the shoreline that is protected. Some advantages of breakwaters are that they provide protection without impairing the usefulness of the beach, and they have a relatively low maintenance cost and long project life. Some disadvantages are high construction costs, a potential navigation hazard, and a potential for starvation and erosion of downdrift beaches. Moreover, the reduction of wave action may have a negative impact on the attractiveness of the recreational beach.

3.1.1.5 Groins

There is already a beach groin system in place within the study area where a total of nine (9) groins spaced every few blocks are located in Rehoboth Beach. The groins were constructed by the State in the period between 1920's through 1960's. The groins are constructed of timber bulkhead and stone filled timber cribbing. Several of the groins have fallen into disrepair and are in poor condition. Groins are long, narrow structures constructed perpendicular to the shoreline for the purpose of building or stabilizing the beach by the trapping of littoral material or retaining artificially placed beachfill. In order for a system of groins to be effective, there must exist an adequate longshore movement of sand, and groins must be designed consistent with the beach profiles. Otherwise downdrift groin compartments may not fill properly and periodic artificial filling of groin compartments may be required. Groins, if not filled initially tend to accumulate material on the updrift side with a corresponding erosion of material on the downdrift side. The resulting irregularly shaped shoreline, together with the presence of the groin structures themselves, make groin-protected shorelines aesthetically displeasing to some individuals. The groins along Rehoboth Beach have been somewhat effective in reducing the natural variability of the shoreline. Modifications and repairs to the existing groins could increase their effectiveness. However, the cost of constructing new groins could be prohibitively high.

3.1.1.6 Beach Nourishment

Beach nourishment is moderate in cost in comparison to other structural alternatives, and directly solves the main erosion problem in the area, a deficiency of sand on the beach. An increase in beach area has an added benefit as a recreational feature as well as aesthetically improving the appearance of the shoreline. In addition, a beach maintained in adequate dimensions has value as a protective measure because beaches are very effective in dissipating wave energy. An important feature of a successful and moderately priced beach nourishment project is to find a suitable borrow area both in terms of the amount and grain size of the material to be used. A large enough dune height and berm width could provide a solution to all of the erosion and storm protection problems of the project area, but the cost to maintain an adequate berm width could be high.

3.1.1.7 Beach Sills

These systems are typically mound-type structures, constructed with rubble, wood sheet pile, tubes, or sand bags, and are aligned parallel to the shoreline in the immediate offshore zone and tied back into the shoreline at both ends. Sills dissipate wave energy and therefore cause sand to be deposited in the region between the sills and shoreline, thus expanding the shoreline and providing an area for wave energy dissipation. Ideally, after the region has filled in, another row of sills may be placed, progressively building up the shoreline until the desired beach width is obtained. Sill structures affect the use of the beach because they are physical barriers to recreational use. Moreover, the durability of the sills in an open ocean environment is questionable, and their susceptibility to vandalism, especially in a high beach use area such as Rehoboth Beach and Dewey Beach, is high.

3.1.2 Non-Structural Storm Damage Reduction Alternatives

3.1.2.1 Flood Insurance

Flood insurance provides compensation for damages through annual premiums which are based on the risk involved. The most recent completed studies for Rehoboth Beach (2 August 1982) and Dewey Beach (17 November 1982) by the Federal Emergency Management Agency (updated maps are still pending) divided the City of Rehoboth Beach and Town of Dewey Beach into four zones based on the probability of flooding from ocean and back bay sources. They include:

V zone - areas inundated by the 100 year coastal flood with accompanying velocity (wave action).

A zone - areas inundated by the 100 year flood.

B zone - areas between limits of the 100 year and 500 year flood; or certain areas subject to 100 year flooding with average depths less than one foot, or where the contributing drainage area is less than one square mile.

C zone - areas of minimal flooding.

After flood insurance zones were established for these areas, the Flood Insurance Rate Maps for these areas were revised to incorporate the zone information.

Flood insurance did not receive further consideration as a viable project alternative because it is currently being practiced, and it does not meet project objectives by preventing or reducing storm damages to structures.

3.1.2.2 Development Regulations

This includes such non-structural measures as zoning, building codes, and bulkhead ordinances. Property owners who wish to develop or rehabilitate structures in Rehoboth and Dewey Beach must first receive the proper permits from the Delaware Department of Natural Resources and Environmental Control (DNREC). DNREC helps the applicant arrange meetings with the appropriate State officials as well as answer any questions on permit requirements. Rehoboth Beach also strictly adheres to the Federal Emergency Management Agency (FEMA) regulations, and recently prevented the construction of a new hotel between Maryland and Olive Avenues because the proposed basement was in the V-zone, an area of 100-year coastal flood with velocity (wave action). Rehoboth Beach has a significant V-zone behind its boardwalk, but beyond the V-zone the flood zone drops to a C-zone, an area of minimal flooding. Rehoboth Beach's building line starts about 10 feet landward of the boardwalk at Rodney Street (the south end of the city), and moves to about 25 feet inward at Philadelphia Street, before bending backwards further. At Wilmington Ave, the building line is 55 feet behind the boardwalk, and increases at Maryland to 75 feet before reaching furthest back at 155 feet at the north end of the city (Lake Avenue). In Dewey Beach, commercial properties are only allowed along Highway One, and some along Rehoboth Bay. No new construction is allowed beyond 30 feet inland from the center line of Dewey Beach's dunes per town ordinance, which is stricter than FEMA's regulations.

Development regulations are an effective means of controlling unwise development in coastal areas. Unfortunately, development regulations cannot prevent storm damages to existing structures within the project area.

3.1.2.3 Land Acquisition

Permanent evacuation of existing areas subject to erosion or inundation involves the acquisition of this land and its structures either by purchase or by exercising the powers of eminent domain. Following this action, all development in these areas is either demolished or relocated. Considering the Rehoboth Beach and Dewey Beach oceanfronts, this plan is both prohibitively expensive and socially unacceptable.

3.2 NO ACTION ALTERNATIVE

The no action alternative would allow beach erosion to continue resulting in an increased risk of property destruction during storms. The base condition (ie. conditions prior to 1994 beachfill conducted by DNREC at Dewey Beach) of this alternative entails continuation of the existing serious beach erosion problem and storm damage threat, with reliance on emergency evacuation measures, floodplain regulations as required under Federal, State and local authorities and flood insurance under Federal programs. Continued erosion would reduce recreational opportunities. This would have the secondary economic effect of reducing tourism which would in turn lower employment levels and the flow of revenue into the area. In the absence of Federal participation, limited State or local efforts to contain erosion and storm damage might be undertaken. However, small scale efforts would not be effective in meeting with the project's needs and goals. Therefore, this alternative was eliminated from further consideration.

3.3 COMPARATIVE IMPACT ANALYSIS OF THE ALTERNATIVES

The beach nourishment alternative best meets the needs and objectives of the project, and was chosen as the basis for further environmental, engineering, design and cost estimate evaluations. The impacts of the no action and beach nourishment alternatives on area resources are presented in Table 3-1.

3.4 PREFERRED ALTERNATIVE: BEACH NOURISHMENT

Because the no action alternative would not accomplish objectives of the project, the beach nourishment alternative is the preferred plan. The beach nourishment plan recommends that a selected berm width along with a selected dune height be maintained in Rehoboth Beach and Dewey Beach. Periodic re-nourishments will be necessary to maintain desired berm widths and dune heights.

3.5 THE SELECTED NED PLAN

Several intermediate alternatives utilizing various beach nourishment schemes were screened during Cycle 3 of the Feasibility Study. Cylcle 3 screening is presented in the Main Report. The plan selected from this screening is the NED (National Economic Development) Plan. The NED plan is the alternative with the highest net benefits for storm damage reduction over costs. The selected (NED) plan, berm and dune restoration through beach nourishment, consists of a 125 foot wide berm at an elevation of +8 NGVD in Rehoboth Beach and a 150 foot wide berm at +8 NGVD in Dewey Beach. Along the length and on top of the berms in both communities lies a dune with a top elevation of +14 feet NGVD and a top width of 25 feet. The selected plan includes approximately 13,500 linear feet of beachfill extending from the northern end of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach. The selected plan tapers into the existing shoreline in the north end at Deauville and in the southern end at North Indian Beach. Details of the selected plan are shown in Figures 3-1 through 3-4. The selected plan includes:

- For Rehoboth Beach, a berm would extend seaward 125 feet from the design line at an elevation of +8 feet NGVD. For Dewey Beach, a berm would extend seaward 150 feet from the design line at an elevation of +8 feet NGVD. The berm in both areas would have a foreshore slope of 1V:15H to mean low water. From this point seaward, the slope would parallel the existing bottom to the depth of closure.

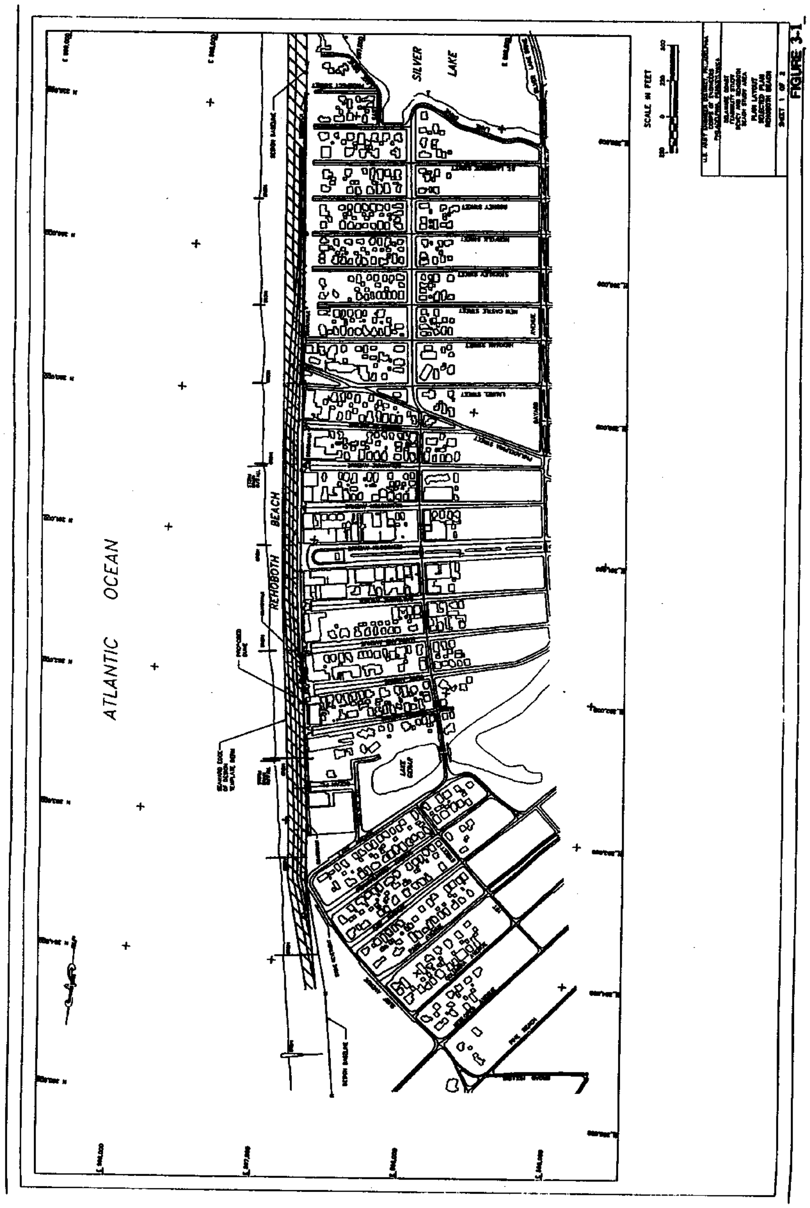
- Both berm plans in both communities would contain a dune on top of the berm with a top elevation of +14 feet NGVD and a top width of 25 feet. The landward and seaward slopes of the dune face would be 1V:5H.

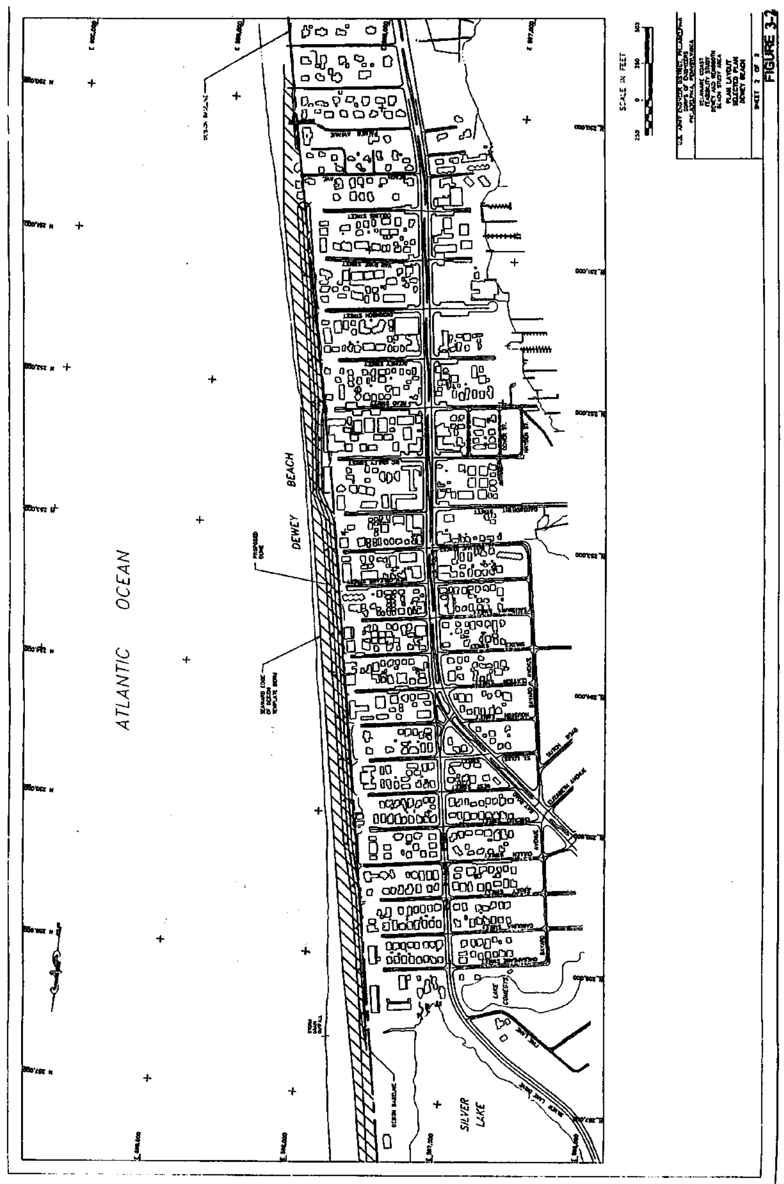
Table 3-1. Comparative Impact Analysis of Potential Effects of the No Action Alternative and the Beach Nourishment Alternative

Alternative: Resource:	No Action	Beach Nourishment
Air	No effect	Temporary degradation due to construction equipment activities which produce smoke, noise, and emissions
Topography and Soils	Continued beach erosion; other than profile, nature of substrate will not change	Beach elevation will be increased; substrate will be basically unchanged
Groundwater	No effect	No effect
Hydrodynamics	No effect	Minor alteration of the local circulation pattern in the immediate vicinity of the borrow area
Water Quality	No effect	Temporary degradation due to sediment resuspension from dredging and beach settling/washout
Wetlands	No effect	No effect
Terrestrial Ecology	No effect	Less mobile organisms will be buried during fill placement; other communities will be temporarily displaced
Aquatic Ecology	No effect	Benthic communities will be temporarily destroyed by dredging activities; this would include some surf clam stocks. Benthic habitat will be temporarily disrupted until recolonization occurs. Finfish habitat will be temporarily disturbed by construction activities and a food source lost until benthic invertebrates recolonize the borrow area.

Table 3-1. Comparative Impact Analysis of Potential Effects of the No Action Alternative and the Beach Nourishment Alternative (continued)

Alternative: Resource:	No Action	Beach Nourishment
Endangered Species	No Effect	Utilization of a hopper dredge could entrain threatened and endangered sea turtles during dredging activities. Initial and subsequent construction activities could potentially disrupt habitat of species such as piping plover within project area on a temporary basis. Long term result would be an increase in habitat available to this species.
Cultural Resources	No Effect	No Effect
Socio-economic	Risk of erosion damages to property will increase. Continued loss of recreational opportunities will result in decreased revenues from tourism and also a subsequent decrease in employment levels.	Erosion protection measures will reduce risk of damage to shore-front property. This will enhance viability of local economy. A short-term effect of construction will be a partial loss of beach use. On a long-term basis, recreational opportunities will be increased, which would permit tourism related businesses to continue at least at current levels.


ATLANTIC OCEAN
REHOBOTH BEACH
SILVER LAKE
SCALE IN FEET
FIGURE 3-1


ATLANTIC OCEAN
DEWEY BEACH
SILVER LAKE
LAKE COMEGYS
SCALE IN FEET
250 0 250 500
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA
DELAWARE COAST
FEASIBILITY STUDY
DEWEY AND REHOBOTH
BEACH STUDY AREA
PLAN LAYOUT
SELECTED PLAN
DEWEY BEACH
SHEET 2 OF 2
FIGURE 3-2

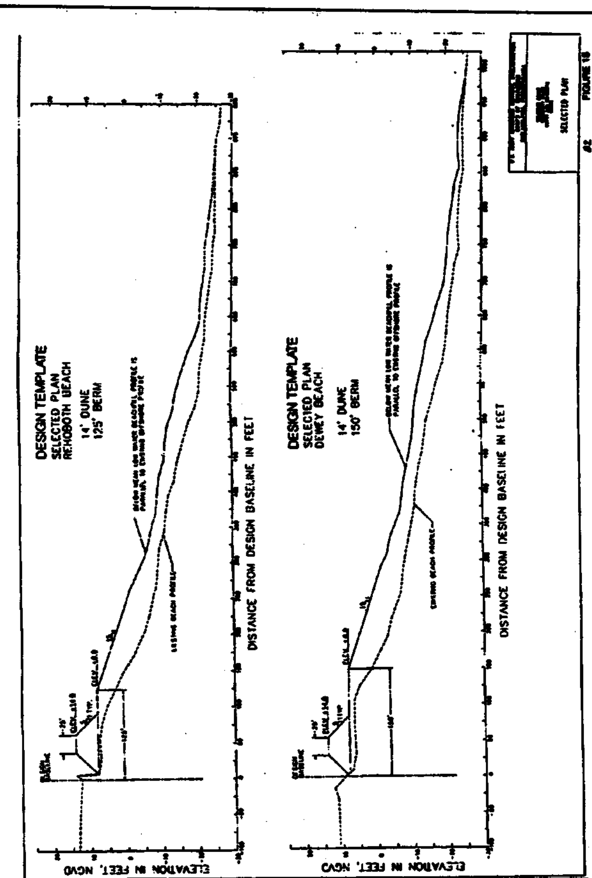


Figure 3-3. Delaware Coast Feasibility Study Design Template for Selected Plans at Rehoboth Beach and Dewey Beach.

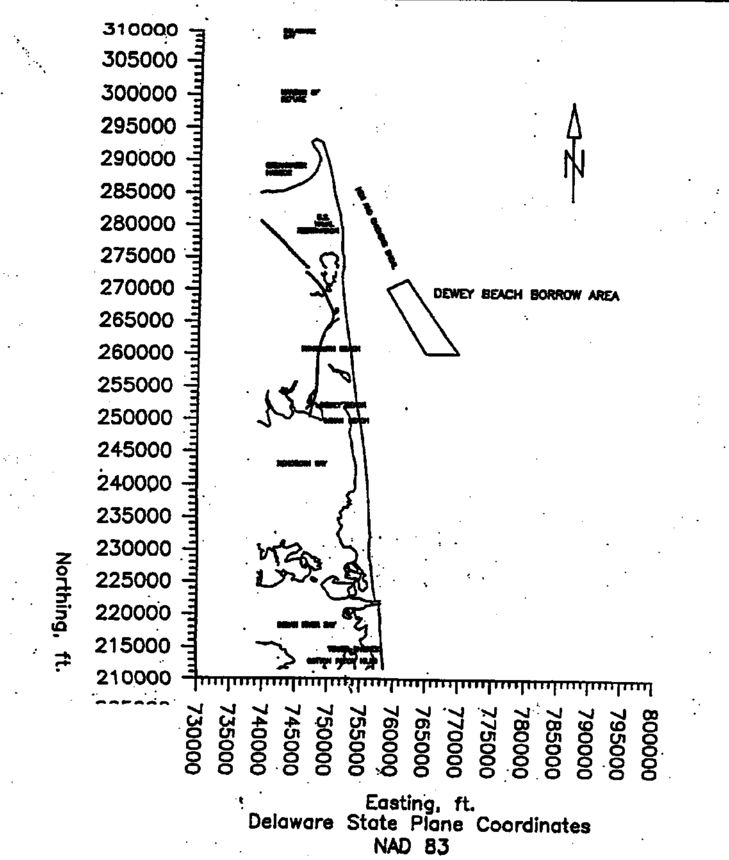


Figure 3-4.
Delaware Coast Feasibility Study
Location for Sand Borrow Site on
Hen and Chickens Shoal.

- A total sand fill quantity of approximately 1.43 million cubic yards is needed for the initial fill placement in Rehoboth Beach and Dewey Beach. This quantity includes tolerance, overfill and advanced nourishment.

- 17.5 acres of planted dune grass and 16,400 linear feet of sand fence for entrapment of sand on the dune would be installed. This includes delineating walkovers and vehicle access ramps.

- 39 dune walkovers and 2 vehicle access ramps over the dune.

- Renourishment of approximately 360,000 cubic yards of sand fill from the offshore borrow area would be required every 3 years for the 50 year project life.

- Beachfill for the proposed project is available from an offshore borrow area containing a minimum of 10 million cubic yards of suitable beachfill material. The borrow area is located approximately 3 miles offshore of the Rehoboth Beach and Dewey Beach area. Details of the borrow site and the borrow material are provided in figure 3-4 and Appendix A of the main report.

- To properly assess the functioning of the proposed plan, monitoring of the placed beachfill, borrow area, shoreline, wave and littoral environment is included with the plan. Environmental monitoring is being addressed through coordination with other interested agencies. The proposed Coastal Monitoring Plan is presented in Appendix A of the main report.

3.6 SUMMARY OF ENVIRONMENTAL EFFECTS OF PLAN

The primary adverse impact of the beach nourishment alternative is the temporary disturbance and destruction of existing benthic resources from dredging operations at the borrow area and fill placement along the shorefront. Dredging in the borrow area will result in a temporary destruction of the benthic community, however, rapid recolonization is expected to occur within one year from the dredging. Minor shifts in benthic community composition may occur following recolonization. Beachfill operations along Rehoboth Beach and Dewey Beach will result in temporary degradation of the existing beach habitat during initial construction and the periodic nourishments. Existing benthic organisms on the beach would become buried as a result from the beachfilling operations. Due to the presence of species adapted to high energy and dynamic conditions, recolonization of the beach area is expected to be rapid. The portion of benthic habitat covered by any seaward extension of the beach would represent a long-term loss, however, this would be offset by the creation of similar habitat. The partial burial of the groins in the project area would represent a long-term loss of rocky inter-tidal habitat occupied by aquatic invertebrates that attract birds and fish. Fish and avian utilization of the immediate shoreline area for feeding would be temporarily disrupted, however, they are expected to return immediately after the disturbance. Dredging and the hydraulic placement of beachfill material will result in temporary higher turbidity levels at the borrow site and waters along the shoreline during construction.

4.0 AFFECTED ENVIRONMENT

4.1 THE PROJECT SITE

The northern portion of the Delaware Atlantic Coast contains a spit-headland complex, baymouth barrier beaches, inland bays, tidal marshes, and Atlantic Coastal Waters. The project area principally involves the Rehoboth-Dewey Beach areas along the Delaware Atlantic Coastline, which extend for a distance of approximately 3 miles north to south, and an offshore sand borrow area on Hen and Chickens Shoal (Fig. 4-1). The northern limit of the project area terminates in Deauville Beach and the southern terminus of the study extends into Indian Beach. The beachfront within these limits is densely developed with houses, stores, and boardwalks with the exception of the Silver Lake area and at Deauville Beach. Because of the high development within the project area, the beach is frequently disturbed by human activities centered around recreation. In Rehoboth Beach, the beaches, for the most part, lack a natural dune system due to this development. Dunes in Dewey Beach are non-existent due to recent storm events and high development. Rehoboth Bay is an inland embayment existing landward from the barrier island at Dewey Beach. Extensive tidal marshes border Rehoboth Bay with the exception of the bay border with Dewey Beach where high development exists. The project impact area also includes an offshore sand borrow site in the ocean. The offshore sand borrow area is approximately 1,120 acres in size, and is located on the southern portion of Hen and Chickens Shoal. This site is within 0.5 to 3.0 miles from the shore in shallow depths ranging from -16 feet to -27 feet (mean low water).

4.2 CLIMATE

4.2.1 Temperature and Precipitation

The Delaware Bay and Atlantic Ocean coastal region experiences a moderate climate associated with the low elevations of the Coastal Plain and the presence of the large water bodies. A moderate winter season results from winds which are heated by warmer water temperatures of the ocean and bays and blown inland. Summer temperatures are in turn moderated by locally generated winds or sea breezes. The warmest period of the year is normally during late July when maximum afternoon temperatures average 89°F. Temperatures exceeding 90°F occur an average of 31 days per year. The coldest period of the year is during late January and early February when early morning temperatures average 24°F. A minimum temperature of 32°F or lower occurs on an average of 90 days per year. Lewes, Delaware has an average annual temperature of 56°F. Lewes experiences an average temperature of 35°F in January and a July average of 75°F. The average winter frost

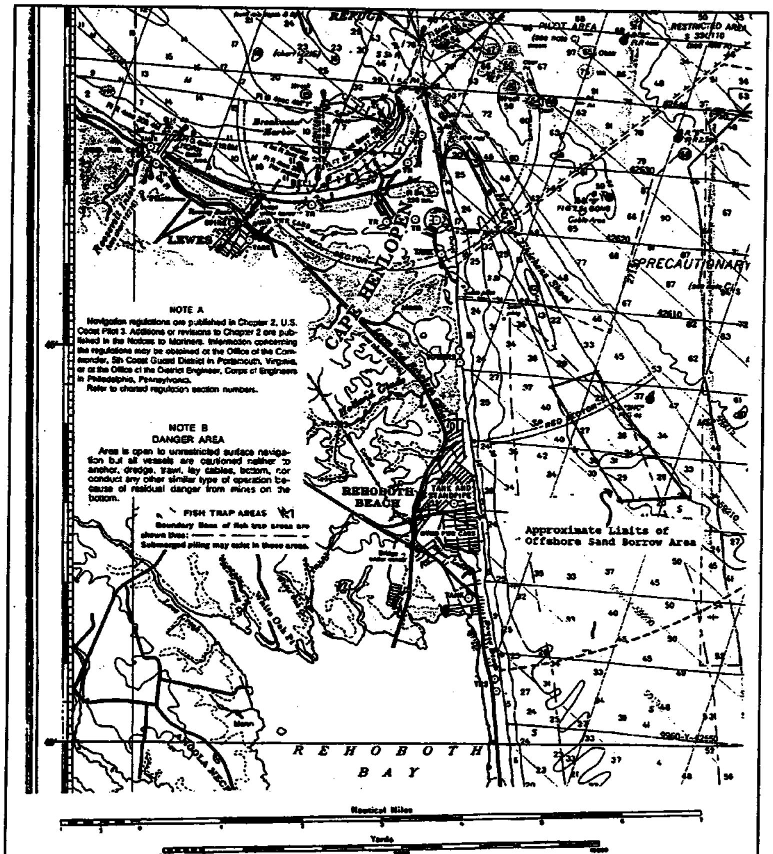


Figure 4-1.
Delaware Coast Feasibility Study
Project Area Map
Rehoboth/Dewey Beach Project
Area.

penetration ranges from 12 to 24 inches. Daily temperature variations along the shore range from 10°F to 20°F throughout the year and are generally much less over the water (Maurer et al., 1974).

Precipitation is generally distributed uniformly throughout the year. August is normally the wettest month, and February is the driest month. Droughts may occur during any month or season, but serious droughts are most frequent during the summer. The average annual precipitation for Lewes is 45 inches. Snowfall averages 16 inches annually at Lewes. Snow is not uncommon along the coast but usually melts rapidly because of lack of cover. Relative humidity along the coast averages 82% annually. Lowest mean relative humidity occurs during November and December (78%), and highest mean relative humidity (84%-86%) occurs from April through August. Monthly mean air temperatures and precipitation are provided in Table 4-1.

4.2.2 Wind

Prevailing winds at Breakwater Harbor are from the southwest, however, winds from other directions are nearly as frequent. The average annual wind-speed along the Delaware Coast is 14.5 mph. In the 5-degree quadrangle nearest the Delaware coast, the winds over the offshore areas are distributed with respect to direction as follows: onshore (northeast, east and southeast) 27 percent; (south) 11 percent; offshore (southwest, west and northwest) 44 percent; and (north) 15 percent. Weather data from Atlantic City, New Jersey, which is approximately 50 miles northeast of the study area, but considered valid as a regional source of data, determined that prevailing winds measured at Atlantic City are from the south and of moderate velocities between 14 to 28 mph. Winds from the northeast have the greatest average velocity of approximately 20 mph. The wind data also show that winds in excess of 28 miles per hour occur from the northeast more than twice as frequently as from any other direction. Winds of 50 mph or more may accompany severe thunderstorms, hurricanes, and general winter storms.

4.2.3 Storms

There are two major types of damaging storms which affect the Delaware coast. They are known as "tropical" (hurricanes and tropical storms) and "extra-tropical" (northeasters) storms. Hurricanes usually diminish in intensity by the time they reach the Delaware coast during their usual northward movement. Remarkably, Delaware has escaped major damages from hurricanes this century. No hurricane storm center has made landfall along the Delaware coast since records have been kept (1871); however, several tropical storms and hurricanes have passed near the Delaware coastline in this period. Northeasters occur more frequently than hurricanes and usually are associated with longer

Table 4-1. Monthly mean air temperatures and precipitation data from Lewes, DE During the Period from 1960-1990.

Month	Mean Temperature (°F)	Mean Precipitation (in.)
January	34.6	3.47
February	36.1	3.33
March	43.3	4.21
April	53.1	3.41
May	62.1	3.54
June	70.7	3.70
July	75.2	4.16
August	74.3	5.36
September	68.4	3.26
October	57.5	3.33
November	48.0	3.49
December	38.5	3.82
Annual	55.5	44.67

Source: Climatological Data Annual Summary Maryland and Delaware 1992; 96:13. NOAA/National Weather Service and received at the National Climatic Data Center, Asheville, North Carolina

durations of storm surge and high waves, which cause considerable beach erosion along the Delaware coast. Storm surge data for the Delaware Coast is provided in Table 4-2.

The most damaging storm to affect the study area during this century was the northeaster of March 6-8, 1962. Two low-pressure areas joined in the ocean off the Mid-Atlantic coast and remained stationary for several days. The sustained high winds over the long fetch produced large waves and a storm surge which lasted over five consecutive high tides. The storm occurred during a period of unusually high astronomical tides. The combined storm tide elevation of 8.1 feet NGVD was the highest recorded in the period of record at Breakwater Harbor, Delaware. Damages resulting from the 1962 storm exceeded $16 million (US Army Corps of Engineers, 1975).

4.2.4 Air Quality

Through the State Implementation Program (SIP), air quality is managed by the Delaware Department of Natural Resources and Environmental Control. The goal of the State Implementation Plan is to meet and enforce the primary and secondary national ambient air quality standards for pollutants. Management concerns are focussed on any facility or combination of facilities which emit high concentrations of air pollutants into the atmosphere. Manufacturing facilities, military bases and installations, oil and gas rigs, oil and gas storage or transportation facilities, power plants, deepwater ports, LNG facilities, geothermal facilities, highways, railroads, airports, ports, sewage treatment plants, and desalinization plants are facilites and activites that may cause air quality problems (NOAA & DECMP, 1980).

The State of Delaware Air Quality Management Section operates one air quality monitoring station in Sussex County at Seaford. Unlike the heavily populated and industrialized New Castle County, Sussex County is primarily rural without any significant sources contributing to air pollution. Overall, air quality in Sussex County is considered to be good, however, exceedences of air quality criteria for ozone designate Sussex County as "marginally" non-attainable in meeting air quality criteria for ozone. With the exception of ozone, all other air quality criteria are met in Sussex County (Personal communication with John Thomas-DNREC Air Quality Management Section).

4.3 GEOLOGY, SOILS, AND TOPOGRAPHY

4.3.1 Geology

Delaware encompasses segments of two regional physiographic-geologic provinces. The extreme northern portion of the State lies within the Appalachian Piedmont province, an area characterized by an exposed bedrock complex consisting of metamorphic and igneous rocks. The eroded surface of this complex slopes south and east to the sea, forming the depositional basement for the wedge-shaped mass of essentially unconsolidated sediments commonly referred to as the Atlantic Coastal Plain Province. This wedge, believed to reach a thickness of approximately 7,800 feet at Fenwick Island, extends eastward beyond the edge of the continental shelf, which is considered a part of the Coastal Plain. As a result, this province can be divided into two sections: a submerged portion, commonly referred to as the continental shelf, and a subaerial or emerged portion, with the present Atlantic Coast shoreline forming the boundary between the two. The area under investigation lies totally within the Coastal Plain approximately 85 miles southeast of the Fall Line (the exposed edge of the Piedmont), and encompasses segments from both the submerged and emerged portions of the province. The boundary between the two portions is characterized by an ever-changing complex of depositional environments associated with the Atlantic barrier system. These environments, which include coastal marshes, tidal lagoons and beach-dune complexes, represent the leading edge of an on-going transgression, which over the past 15,000 years has caused the shoreline complex to advance across approximately two-thirds of the Coastal Plain province to its present position. This transgression is occurring in response to a relative rising of the sea level. The current rate of rise is estimated to be approximately one foot per century along the Delaware Atlantic Coast.

The shoreline of the Atlantic Coast of Delaware consists of a continuous, wide, sandy baymouth barrier except for a break at Indian River Inlet. Coastal barrier beaches may be considered a continually moving geomorphic form with materials eroding from the beach face and accreting landward and upwards across the coastal lagoonal areas.

4.3.2 Soils and Topography

The Coastal area can be divided into two zones of similar geology; the Cape Henlopen spit complex; and the baymouth barrier, lagoon, and highland complex between Rehoboth Beach and Fenwick Island. The Cape Henlopen complex is comprised of a washover barrier tract north of Rehoboth Beach extending to Cape Henlopen, a beach face/berm and dune system, and a large tidal flat. The stratigraphy of sediments in the spit dune area indicate beach and spit sands and gravels interbedded with shallow marine-estuarine silts (Kraft, 1971).

The second area, the baymouth barrier, lagoon and highland complex is characterized by rapid erosion, predominantly coastal washover erosion. The barrier erodes at the beach face and nearshore area and accretes in a landward direction. The beach face is rather steep and the berm is comprised of horizontally laminated coarse to medium sand. A generalized vertical sequence of sediments found at Dewey Beach and south indicate dune washover sands overlying back barrier marsh sediments (clayey sand and peat), which contain tree stumps from an ancient pine forest. Below this are tidal delta sands and gravels followed by lagoonal sand and silt, and in some cases a small underlying pocket of beach sand. Marsh muds and peats are then encountered followed by a marsh fringe of muddy sand and grass roots and/or tree stumps. Pleistocene coastal sediments then form the base.

Table 4-2. Breakwater Harbor, Lewes, Delaware. Twenty Highest Recorded Annual Peak Stages 1919 to 1992

Rank	Max Stage Ft NGVD(1)	Storm Type(2)	Date
1	8.1	NE	3/6/1962
2	7.3	NE	1/4/1992
3	6.7	NE	3/3/1994
4	6.6	HUR	9/27/1985
5	6.6	NE	10/25/1980
6	6.6	HUR	10/22/1961
7	6.5	NE	3/29/1984
8	6.3	HUR	10/14/1977
9	6.2	NE	10/31/1991
10	6.2	NE	10/23/1953
11	6.1	NE	12/22/1972
12	6.0	NE	1/13/1964
13	6.0	NE	12/9/1973
14	6.0	NE	1/11/1947
15	5.9	NE	1/10/1956
16	5.9	NE	1/2/1987
17	5.9	NE	11/10/1969
18	5.8	HUR	12/12/1960
19	5.8	NE	1/29/1922
20	5.7	NE	5/24/1967

1 Values rounded to nearest 0.1 ft.
2 HUR = hurricane, NE = northeaster

When large storms occur, the beach berm sand may be washed over the barrier into coastal lagoons, sometimes exposing the marsh peats and tree stumps normally buried five to seven feet below the beach berm system. This extensive forest has been exposed along the length of the Delaware Coast, except at the Pleistocene highlands at Bethany and Rehoboth Beach. As a result of the beach erosion, rounded masses of peat and marsh mud called "marshrollers" are often found moving along the surf adjacent to the eroding shoreline.

The subtidal topography off Cape Henlopen differs from areas further south along the coast (ie. Bethany Beach). Maurer et al., 1974 describes the subtidal bottom off Cape Henlopen as a beach sloping to a flat shallow bottom (9 m), rising on Hen and Chickens Shoal, then dropping rapidly into a series of deep holes (24 m) and elongate depressions. Hen and Chickens Shoal was formed and is maintained by ebb tide currents depositing fine sand. The sediment can be generally characterized as dominated by medium sands (0.2 to 0.6 mm) (Maurer et al.,1974, Dames and Moore, 1993). The bottom sediments, depending on the location, range from fine sand to gravel and shell debris (Maurer et al.,1974, Kraft, 1971). The presence of large rocks and small boulders are noted by Maurer et al., 1974 as occurring on the deeper bottom east of Hen and Chickens Shoal.

The proposed sand borrow area is located on the southern end of Hen and Chickens Shoal from 0.5 - 3.0 miles offshore in depths ranging from 23-31 feet. This area is separated from the south by Shark's Channel, which is a scoured area known for swift currents (Dames and Moore, 1993).

4.4 COASTAL HYDRAULICS

4.4.1 Tides

The Delaware coast experiences semidiurnal tides where two nearly equal high tides and two nearly equal low tides occur daily. The average tidal period is 12 hours and 25 minutes, which produces two full tidal periods requiring 24 hours and 50 minutes. These periods result in the tide height extremes (highs and lows) to appear almost one hour (50 minutes) later each day. Rehoboth Beach experiences a mean tide range of 3.9 feet with a spring tide range of 4.7 feet.

4.4.2 Waves

Meteorological data collected over the open ocean for a period of 20 years (1956-1976) are used to calculate sea and swell conditions at 3 hour intervals. This procedure is known as hindcasting, which is the best available procedure to describe local wave regimes. Two stations (WIS 65 and 66) along the

Delaware coastline at water depths of 18 meters (59.1 ft.) were used to represent the southern and northern Delaware coastlines. Wave statistics developed include: "significant wave height", which is the average height of the highest one-third of the waves during a given time interval; "wave period", which is the period corresponding to the peak in the wave energy-period spectrum; and "wave direction", which is the mean direction from which the waves are moving relative to true north. The highest significant wave heights reported from the 3 hour hindcasts for Station 65, and 66 are 7.7 meters (25 feet), and 5.0 meters (16.5 feet), respectively. These values were both recorded during the March 1962 Northeaster. Waves approach the coast from NNE, NE, E, SE, and S for each station, with the most frequent occurrence from the east and southeast directions. The actual wave spectrum at any particular time may show considerable local variation as the computed waves offshore at a depth of 18 meters propagate landward and are modified by localized irregular bathymetry, shoreline stabilization structures and the tidal currents from the Delaware Bay and Indian River Inlet.

In order to obtain localized wave data within the project area, a directional wave gage was deployed offshore of Dagsworthy Street in the town of Dewey Beach. The gage was deployed in October 1992 and was operated without interruption through December 1993. During the 15 months the gage was deployed, the observed data shows the same trend as the 20 year WIS hindcast. The predominant wave direction is from the east and southeast, with the highest waves being recorded from the east-northeast during storms. The highest wave height recorded was during the December 1992 Northeaster at 4.1 meters (13.5 feet).

4.4.3 <u>Currents</u>

There are two general classes of currents which can cause tangible effects on the stability of the study area shoreline. The first class is referred to as tidal currents, which are generated by hydraulic head differences between water levels in the ocean and the back bay areas. The periodic rise and fall of the ocean water level adjacent to barrier islands is the principal driving force for the ebb and flood of tidal currents. Tidal inlets such as Indian River Inlet provide the connection between ocean and back bay areas and constitute the zone in which the effects of tidal currents are most pronounced. The tidal currents at inlets can be important mechanisms for transport of sediments in the coastal zone, particularly as they interact with longshore wave induced currents and wind to shape many of the typical morphological features associated with barrier island-tidal inlet zones. The second general class of currents considered important to coastal shoreline stability is the longshore current. These currents are set up in the breaker zone adjacent to beaches, and are caused by the longshore component of momentum in the waves breaking at an angle relative to the shore alignment. The turbulence associated with wave breaking causes suspension of sediments which can then be transported in the along-shore direction by the longshore current. The predominant direction of the longshore transport of sand at Rehoboth Beach and Dewey Beach is northward. Along the central portion of barrier beaches and headland beaches such as Dewey Beach and Rehoboth Beach, longshore currents provide the primary mechanism for sand transport. However, the importance of tidal current increases closer to tidal inlets.

4.5 WATER QUALITY OF DELAWARE ATLANTIC COASTAL WATERS

4.5.1 Temperature and Salinity

Mixing occurs in nearshore waters due to the turbulence created from wave energy contacting shallower depths. This mixing becomes less prominent in greater depths where stratification can develop during warm periods. Water temperatures generally fluctuate between seasonal changes. The average temperature range is from 3.7°C (January) to 21.4°C (October). The most pronounced temperature differences are found in the winter and summer months. Warming of coastal waters first becomes apparent near the coast in early spring, and by the end of April thermal stratification may develop. Under conditions of high solar radiation and light winds, the water column becomes more strongly stratified during the months of July to September. The mixed layer may extend to a depth of only 12 to 13 feet. As warming continues, however, the thermocline may be depressed so that the upper layer of warm, mixed water extends to a depth of approximately 40 feet. Salinity concentration is chiefly affected by freshwater dilution. Salinity cycles result from the cyclic flow of streams and intrusions of continental slope water from far offshore onto the shelf. Continental shelf waters are the least affected by freshwater dilution, and have salinity concentrations varying between 30 parts per thousand (ppt) and 35 ppt. Coastal waters are more impacted by freshwater dilution and may have salinities as low as 27 ppt. Salinity is generally at its maximum at the end of winter. The voluminous discharge of fresh water from the land in spring reduces salinity to its minimum by early summer. Surface salinity increases in autumn when intrusions from offshore more than counterbalance the inflow of river water, and when horizontal mixing becomes more active as horizontal stability is reduced. At Hen and Chickens Shoal, Maurer et al., 1974 described that salinity fluctuates little throughout the tidal cycle, with depth, and between sampling stations, and was found to range from 27.2 ppt (April) to 29.8 ppt (October). Mean dissolved oxygen values at Hen and Chickens Shoal were 3.68 ppm (January) to 8.01 ppm (August) (Maurer et al., 1974). Recent water sampling was conducted within the proposed sand borrow site just above the substrate in depths ranging from 23 ft to 31 ft. The average temperature was 14.2°C and the average dissolved oxygen and salinities were 8.43 mg/L and 32.3 ppt, respectively (Dames and Moore,1993).

4.5.2 Water Quality Parameters

Water quality is generally good in the nearshore because of the constant circulation provided by waves and currents. In 1973-74, water quality was sampled at three stations in Hen and Chickens Shoal by DNREC (Maurer et al., 1974). No general patterns regarding site locations, seasons, night-day, and state-of-the tide emerged from the data. The highest concentrations of heavy metals were silver (0.06-0.14 ppm), lead (<0.1-0.38 ppm), and nickel (<0.1-0.21 ppm). Arsenic levels were below 0.04 ppm. Ammonia nitrogen ranged from 1.6-5.5 ppm.

Beach closings occasionally occur due to high coliform levels usually after high rainfall events. Rehoboth Beach has the most frequent beach closings due to a high concentration of storm sewer outfalls which discharge on the beach. The State of Delaware Division of Public Health frequently monitors water quality for recreation between the months of May through September. No beach closings or swimmer advisories were issued between 1992 and 1994 for Rehoboth and Dewey Beaches (Pingree,1994).

Sediments in the borrow area are composed of medium to fine sands with very low amounts of silts and clays. Organic contaminants and metals are typically low in sediments dominated by sands. Sediments in Hen and Chickens Shoal were sampled in 1973-74 and found that with the exception of zinc and lead, the metal concentrations were lower than concentrations in water in all cases (Maurer et al.,1974). The borrow material is not expected to be chemically contaminated because the substrate is primarily sand that has been subjected to a high energy-current regime. This coupled with the absence of dumping activities, industrial outfalls, or contaminated water infers the low probability that the borrow material would be contaminated by pollutants.

4.6 TERRESTRIAL ECOLOGY OF AFFECTED AREA

4.6.1 General

The entire project area contains a high energy beach with land features such as headlands in the north (Rehoboth Beach) and barrier island to the south (Dewey Beach). The barrier island is flanked on the west by Rehoboth Bay and the Atlantic Ocean on the east. Primary and secondary dunes are basically non-existent throughout the majority of the project area due to high development and erosion. Exceptions to this are at Silver Lake and the northern terminus of the project area at Deauville Beach just north of the bend in Lakeshore Drive in Rehoboth Beach. In

1994, construction of several single-family homes began immediately behind the primary dune at Silver Lake.

4.6.2 Dunes

Although typical beach dunes and the habitats associated with them are either fragmented and highly disturbed or are non-existent within the project area, a few elements of beach dune flora and fauna are still present. The largest stretch of undeveloped beachfront exists at the northern end of the project area at Deauville Beach which extends for approximately 2,800 feet. The beaches of Cape Henlopen State Park and Delaware Seashore State Park exhibit unfragmented natural settings where typical dune flora and fauna are present. The following discussion on beach dunes mainly pertains to surrounding areas outside of the Dewey Beach and Rehoboth Beach project impact area, however, some of the dune flora and fauna discussed may still be present in limited pockets. Developed land and various terrestrial habitat types are presented in Figure 4-2.

In typical undisturbed beach profiles of the Delaware Atlantic Coast, the primary dune is the first dune landward from the beach. The flora of the primary dune are adapted to the harsh conditions present such as low fertility, heat, and high energy from the ocean and wind. The dominant plant on these dunes is American beachgrass (Ammophila breviligulata), which is tolerant to salt spray, shifting sands and temperature extremes. American beachgrass is a rapid colonizer that can spread by horizontal rhizomes, and also has fibrous roots that can descend to depths of 3 feet to reach moisture. Beachgrass is instrumental in the development of dune stability, which opens up the dune to further colonization with more species like seaside goldenrod (Solidago sempervirens), sea-rocket (Cakile edentula) and beach clotbur (Xanthium echinatum).

The secondary dunes lie landward of the primary dunes, and tend to be more stable resulting from the protection provided by the primary dunes. The increased stability also allows an increase in plant species diversity. Some of the plant species in this zone include: beach heather (Hudsonia tomentosa), coastal panic grass (Panicum amarum), saltmeadow hay (Spartina patens), broom sedge (Andropogon virginicus), beach plum (Prunus maritima), seabeach evening primrose (Oenothera humifusa), sand spur (Cenchrus tribuloides), seaside spurge (Ephorbia polygonifolia), joint-weed (Polygonella articulata), slender-leaved goldenrod (Solidago tenuifolia), and prickly pear (Opuntia humifusa).

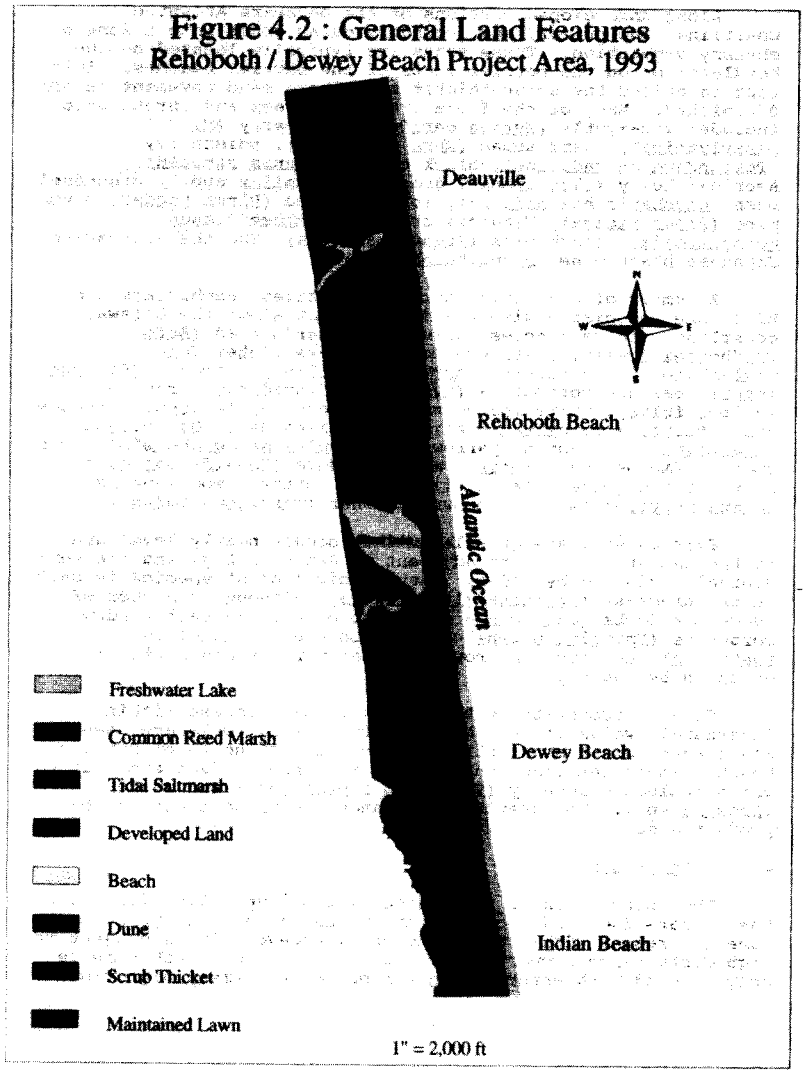


Figure 4.2 : General Land Features
Rehoboth / Dewey Beach Project Area, 1993
Deauville
Rehoboth Beach
Atlantic Ocean
Dewey Beach
Indian Beach
Freshwater Lake
Common Reed Marsh
Tidal Saltmarsh
Developed Land
Beach
Dune
Scrub Thicket
Maintained Lawn
1" = 2,000 ft

Along undeveloped portions of the Delaware Atlantic Coastline, the primary and secondary dunes grade into a zone of shrubby vegetation. These zones are typically located on the headlands or on the barrier flats of the barrier beaches. This zone is called the scrub-thicket zone where sand movement is more diminished. Many of the flora are dwarf trees and shrubs which include: wax-myrtle (Myrica cerifera), bayberry (M. pensylvanica), dwarf sumac (Rhus copallina), poison ivy (Toxicodendron radicans), black cherry (Prunus serotina), American holly (Ilex opaca), greenbrier (Smilax spp.), groundsel bush (Baccharis halimifolia), loblolly pine (Pinus taeda), pitch pine (Pinus rigida), Virginia creeper (Parthenocissus quinquefolia), beach plum (Prunus maritima), and the non-native Japanese black pine (Pinus thunbergii).

A number of non-marine mammals, reptiles, amphibians and birds are associated with the dune habitat along the Delaware coastline. These species include: Fowler's toad (Bufo woodhousei fowleri), eastern hognose snake (Heterodon platyrhinos), box turtle (Terrapene carolina), raccoon (Procyon lotor), eastern cottontail (Sylvilagus floridanus), red fox (Vulpes fulva), white-footed mouse (Peromyscus leucopus), meadow vole (Microtus pensylvanicus), white-tailed deer (Odocoileus virginianus), savannah sparrow (Passerculus sandwichensis), song sparrow (Melospiza melodia), mourning dove (Zenaida macroura), gray catbird (Dumetella carolinensis), northern mockingbird (Mimus polyglottos), and brown thrasher (Toxostoma rufum).

Salt marshes are grasslands that occupy nearly level areas on the back-barrier flats adjacent to Rehoboth Bay, and are semi-diurnally flooded by tides. The principal plant species is salt marsh cordgrass (Spartina alterniflora), although a number of succulent forbs (Salicornia sp.) also occur, and salt meadow cordgrass (Spartina patens) and common reed (Phragmites australis) may form a narrow band near more upland sections occupied by the type.

Several freshwater wetland pockets have formed within interdunal swales at Cape Henlopen State Park, Delaware Seashore State Park, and a short stretch of beach just north of Bethany Beach. These wetlands contain rare and unique plant communities which include cranberry (Vaccinium macrocarpon) and sundew (Drosera sp.). No interdunal wetlands are present within the project area.

4.6.3 Upper Beach

The upper beach or supralittoral zone typically lies below the primary dune and above the intertidal zone. An upper beach zone is present within the study area, however, it is subject to high disturbance from human activity. The upper beach zone is only covered with water during periods of extremely high tides and large storm waves. The upper beach habitat is characterized by sparse vegetation and few animals. This zone has fewer biological interactions than the dunes, and organic inputs are scarce. The most active organism in this zone is the ghost crab (Ocypoda quadrata). This crab lives in semi-permanent burrows near the top of the shore, and it is known to be a scavenger, predator, and deposit sorter. The ghost crab is nocturnal in its foraging activities, and it remains in its burrow during the day. In addition to ghost crabs, species of sand fleas or amphipods (Talitridae), predatory and scavenger beetles and other transient animals may be found in this zone.

Many species of shorebirds inhabit the beach during the spring and fall migrations, although most are even more likely to be found on more protected sand and mud flats, tidal marshes, or along the Delaware Bay shoreline (especially in spring when large numbers of horseshoe crab eggs are available). Shorebirds feed on small individuals of the resident infauna and other small organisms brought in with waves. Common shorebird species include sanderling (Calidris alba), dunlin (C. alpina), semipalmated sandpiper (C. pusilla), western sandpiper (C. mauri), and willet (Catoptrophorus semipalmatus). Sanderling, dunlin, and western sandpiper also occur on the beach throughout the winter. Colonial nesting shorebird habitat is increasingly under pressure from development and human disturbance along Delaware's Atlantic beaches. Nesting birds such as common tern (Sterna hirundo), least tern (Sterna antillarum), black skimmer (Rynchops niger) and American oystercatcher (Haematopus palliatus) are frequent spring and summer inhabitants on unvegetated dunes and upper beaches at Cape Henlopen and Delaware Seashore State Parks. Undeveloped beaches such as these State Parks are critical for nesting pairs of the Federal and State threatened piping plover (Charadrius melodus). High beachfront development and human disturbance in the Dewey Beach and Rehoboth Beach project area has consequently forced nesting shorebirds to seek the remaining undeveloped beaches.

Several species of gulls are common along Delaware's shores, and are attracted to forage on components of the beach wrack such as carrion and plant parts. These gulls include the laughing gull (Larus atricilla), herring gull (L. argentatus), and ring-billed gull (L. delawarensis).

4.7 AQUATIC ECOLOGY OF AFFECTED AREA

4.7.1 Upper Marine Intertidal Zone

The upper marine intertidal zone is also primarily barren, however, more biological activity is present in comparison to the upper beach. Organic inputs are derived primarily from the ocean in the form of beach wrack, which is composed of drying seaweed, tidal marsh plant debris, decaying marine animals, and miscellaneous debris that washed up and deposited on the beach. The beach wrack provides a cooler, moist microhabitat suitable to crustaceans such as the amphipods: *Orchestia* spp. and *Talorchestia* spp., which are also known as beach fleas. Beach fleas are important prey to ghost crabs. Various foraging birds and some mammals are attracted to the beach fleas, ghost crabs, carrion and plant parts that are commonly found in beach wrack. The birds include gulls, shorebirds, fish crows, and grackles.

4.7.2 Intertidal Zone

The intertidal zone contains more intensive biological activity than the other zones. Shifting sand and pounding surf dominate a habitat which is inhabited by a specialized fauna. The beach fauna forms an extensive food-filtering system which removes detritus, dissolved materials, plankton, and larger organisms from in-rushing water. The organisms inhabiting the beach intertidal zone have evolved special locomotory, respiratory, and morphological adaptations which enable them to survive in this extreme habitat. Organisms of this zone are agile, mobile, and capable of resisting long periods of environmental stress. Most are excellent and rapid burrowers. Frequent inundation of water provides suitable habitat for benthic infauna, however, there may be a paucity in numbers of species. Intertidal benthic organisms tend to have a high rate of reproduction and a short (1 to 2 years) life span (Hurme and Pullen, 1988). This zone contains an admixture of herbivores, primary carnivores, and some high order carnivores such as the mole crab (*Emerita* sp.). A number of interstitial animals (meiofauna) are present feeding among the sand grains for bacteria and unicellular algae, which are important in the beach food chain. In 1978, extensive sampling for invertebrate infauna was performed by the U.S. Fish and Wildlife Service and Corps of Engineers on the beaches within the Delmarva Peninsula, Maryland. There were four dominant species of invertebrate infauna in this zone, which were the mole crab (*Emerita talpoida*), a haustorid amphipod (*Haustorius canadensis*), the coquina clam (*Donax variabilis*), and spionid worm (*Scolelepis squamata*). The epifaunal blue crab (*Callinectes sapidus*) and the lady crab (*Ovalipes ocellatus*) were also found in or near this zone. These species withdraw to the nearshore subtidal zone during the winter months and return to the intertidal zone when conditions are more favorable. These invertebrates are prey to various shorebirds and nearshore fishes such as the Atlantic silverside (*Menidia menidia*), and juveniles of spot (*Leiostomus xanthurus*), kingfish (*Menticirrhus saxatilus*), and bluefish (*Pomatomus saltatrix*). The horseshore crab (*Limulus polyphenus*) is a common inhabitant of Atlantic Coastal areas and utilizes the sandy beaches (particularly of Delaware Bay) to lay eggs.

Benthic macroalgae grow attached to the bottom substrate in the intertidal zone where they are alternately exposed and submerged as the tides ebb and flow. The substrate along the Delaware Atlantic Coast is mainly composed of shifting sands and shell fragments making it too unstable for large colonies of benthic algae to proliferate. Colonies do attach on hard, stable substrates provided by peat banks, shell bottoms, reefs, and man-made structures such as pilings, jetties, buoys and bridges. Various species of benthic macroalgae representing the phyla Chlorophyta and Phaeophyta are found in Delaware's coastal waters.

The nine rock groins in Rehoboth Beach and Dewey Beach represent an artificial rocky intertidal zone. In addition to providing a hard substrate for the attachment of benthic macroalgae, the groins also contain suitable habitats for a number of aquatic and avian species. Barnacles, small crustaceans, polychaetes, molluscs and a variety of shorebirds may reside on, above and around these structures. Mussels (*Mytilus sp.*) are prevalent on the rock surfaces. These structures are also used by various finfish for feeding and shelter.

4.7.3 Nearshore and Offshore Zones

The nearshore coastal zone generally extends seaward from the subtidal zone to well beyond the breaker zone (U.S. Army Corps of Engineers, 1984). This zone is characterized by intense wave energies that displace and transport coastal sediments. The offshore zone generally lies beyond the breakers and is a flat zone of vairable width extending to the seaward edge of the Continental Shelf. Hurme and Pullen (1988) describe the nearshore zone as an indefinite area that includes parts of the surf and offshore areas affected by nearshore currents. The boundaries of these zones may vary depending on relative depths and wave heights present (Figure 4-3). From Rehoboth Beach, the nearshore bottom gently slopes to a flat bottom (approx. 9 m) and then rises on Hen and Chickens Shoal. An exception to the relativley shallow depths is the presence of a deep trough which is a remnant of the ancient Delaware River Channel. Prominent shoal complexes usually occur within the nearshore zone. Hen and Chickens Shoal is located southeast from Cape Henlopen and is formed by ebb tide currents carrying and depositing sands from the lower Delaware Bay (USFWS,1991).

The following paragraphs discuss planktonic, pelagic and benthic biological resources associated with Delaware coastal waters, which may overlap nearshore waters with offshore waters. The proposed sand borrow site on Hen and Chickens Shoal will be referred to as the proposed offshore borrow site.

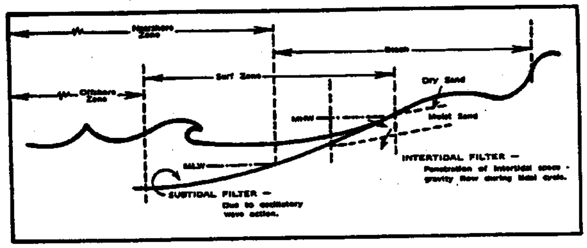


Figure 4-3.
Delaware Coast Feasibility Study
Coastal Zonation (Burns et al. 1988)

4.7.3.1 Plankton

Plankton are collectively a group of interacting minute organisms adrift in the water column. Plankton are commonly broken into two main categories: phytoplankton (plant kingdom) and zooplankton (animal kingdom).

Phytoplankton are the primary producers in the aquatic marine ecosystem, and are essential trophic links to higher organisms in the marine food chain. Light and chemical energy are converted into organic compounds which can be assimilated by higher organisms in the food chain. Phytoplankton production is dependent on light penetration, available nutrients, temperature and wind stress. Phytoplankton production is generally highest in nearshore waters. Seasonal shifts in species dominance of phytoplankton are frequent. Dinoflagellates are generally abundant from summer through fall and diatoms are dominant during the winter and early spring. Approximately 126 species of phytoplankton were identified in Delaware's coastal waters representing the following phyla: Chlorophyta, Chromophyta, Pyrrophyta, Euglenophyta, and Procaryota.
The most prevalent species and their season of dominance are as follows:

Nitzschia seriata - winter
Skeletonema costatum - late winter, early spring

Guinarkia flaccida - spring
Pyramimonas sp. - spring, early summer
Cryptomonas acuta - summer
Katodinium rotundatum - mid-summer
Chrysochromulina sp. - summer

Zooplankton provide an essential trophic link between primary producers and higher organisms. Zooplankton represent the animals (vertebrates and invertebrates) that are adrift in the water column, and are generally unable to move against major ocean currents. Many organisms may be zooplankton at early stages in their respective life cycles only to be able to swim against the currents (nektonic) in a later life stage, or to be a part of the benthic community. Zooplankton are generally either microscopic or barely visible to the naked eye. Zooplankton typically exhibit seasonal variances in species abundance and distribution, which may be attributed to temperature, salinity and food availability. In marine environments, seasonal peaks in abundance of zooplankton distinctly correlate with seasonal phytoplankton peaks. These peaks usually occur in the spring and fall. Sampling in the lower Delaware Bay by Watling and Maurer (1976) revealed the presence of 60 species representing the following phyla: Protozoa, Cnidaria, Ctenophora, Ectoprocta, Annelida, Mollusca, Arthropoda, Chaetognatha and Chordata. Calanoid copepods are a dominant component of the zooplankton in Delaware coastal waters (Dupont et al.,1972). Peaks in calanoid copepod dominance are known to occur during October-November, which may be attributed to the high phytoplankton productivity. Zooplankton species characteristic of coastal areas include: Acartia tonsa, Centropages humatus, C. furatus, Temora longicornis, Tortanus discaudatus, Eucalanus pileatus, Mysidopsis bigelowi (mysid), and Crangon septemspinosa (sand shrimp).

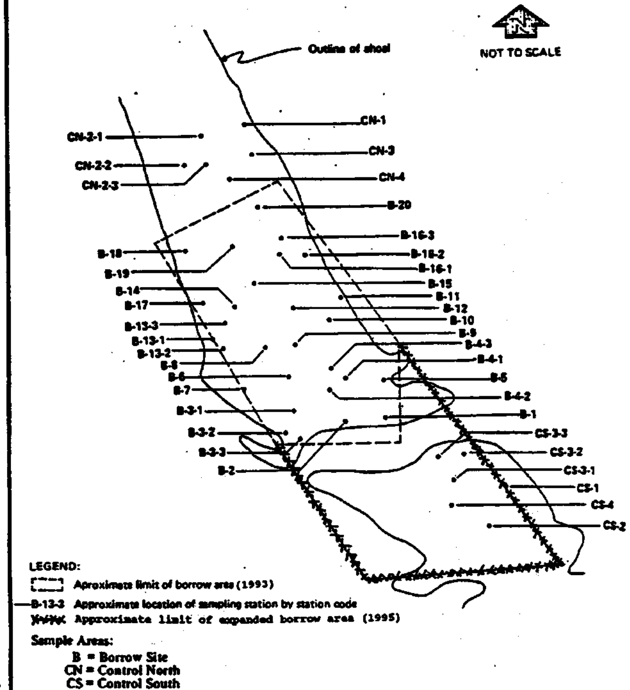
4.7.3.2 Macroinvertebrates

The nearshore and offshore zones of the Delaware Coast contain a wide assemblage of invertebrate species inhabiting the benthic substrate and open water. Invertebrate phyla existing along the coast are represented by Cnidaria (corals, anemones, jellyfish), Platyhelminthes (flatworms), Nemertinea (ribbon worms), Nematoda (roundworms), Bryozoa, Mollusca (chitons, clams, mussels, etc.) Echinodermata (sea urchins, sea cucumbers, sand dollars, starfish), and the Urochordata (tunicates).

Benthic macroinvertebrates are those dwelling in the substrate (infauna) or on the substrate (epifauna). Benthic invertebrates are an important link in the aquatic food chain, and provide a food source for most fishes. Various factors such as hydrography, sediment type, depth, temperature, irregular patterns of recruitment and biotic interactions (predation and competition) may influence species dominance in benthic communities. Benthic assemblages in Delaware coastal waters exhibit seasonal and spatial variability. Generally, coarse sandy sediments are inhabited by filter feeders and areas of soft silt or mud are more utilized by deposit feeders.

Hen and Chickens Shoal is a dynamic, heterogeneous area heavily influenced by the tidal flow from Delaware Bay. Although several pockets of fine materials are present, Hen and Chickens Shoal is generally composed of fine-medium sands, which influence the composition of the benthic assemblage. The following benthic species were found to be most abundant in the nearshore waters off of Cape Henlopen by Leathem et al. (1983): Aricidea catherinae (paraonid polychaeta), Spiophanes bombyx (spionid polychaeta), Tellina agilis (tellinid bivalvia), Mediomastus ambiseta (capitellid polychaeta), Brania wellfleetensis (syllid polychaeta), Nephtys picta (nephtyid polychaeta), Unciola irrorata (aorid amphipoda), Paranaitis speciosa (phyllodocid polychaeta), Nucula annulata (nuculid bivalvia), and Ensis directus (solenid bivalvia). Maurer et al., 1974 recorded a total of 168 species obtained from quarterly sampling at Hen and Chickens Shoal. The amphipod (Parahaustorius longimerus) was the dominant species with lesser numbers of other haustorid amphipods and the molluscs: surfclam (Spissula solidissima) and (Tellina agillis). High numbers of blue mussels (Mytilus edulis) and a fringed worm (Tharyx acutus) were abundant in samples obtained from deep-water stations east of the shoal. These deep-water stations contained hard bottoms composed of coarse sand and pebbles with extensive shell debris and small silt pockets.

In June 1993, a benthic-sediment assessment focussing on infauna species was conducted in the proposed offshore sand borrow site located on Hen and Chickens Shoal to establish a baseline for the benthic macroinvertebrate assemblages within the proposed borrow site. Other objectives were to identify the presence of any commercial and/or recreationally important benthic macroinvertebrates, and to identify the presence of ecologically important benthic communities within the proposed sand borrow site. Two control areas were situated north and south of the proposed sand borrow site to offer comparisons with the data. Figure 4-4 identifies the sample locations in relation to the proposed borrow site. The sediments inhabited by the benthic community were primarily composed of medium sands (>0.25 mm but <0.43 mm) with the exception of three stations, which were dominated by fine sands (>0.15 mm but <0.25 mm). Although the sampling only represented the benthic assemblage at a single point in time, a total of sixty-three species were identified at the species-level out of a total of 82 taxa (Table 4-3). Several species were dominant based on their frequency of occurrence per study area within the borrow site. These species are: Protohaustorius wigleyi (haustorid amphipod), Chiridotea tuftsi (isopod), Parahaustorius spp., Tellina agilis (bivalve), and Nephtys bucera (polychaete). The surfclam (Spisula solidissima) was the only commercial species identified from the benthic



BENTHIC-SEDIMENT ASSESSMENT
1993 STATION LOCATIONS
HEN AND CHICKENS SHOAL, DELAWARE

Figure 4-4.
Delaware Coast Feasibility Study Benthic-Sediment Assessment 1993 Station Locations at Hen and Chickens Shoal, Delaware.

BENTHIC MACROINVERTEBRATES*
HEN AND CHICKENS SHOAL, DELAWARE
June 23 and 24, 1993

- P. Cnidaria
  - C. Anthozoa
    - Anthozoa
- P. Nemertinea
  - Nemertinea
- P. Annelida
  - C. Polychaeta
    - F. Ampharetidae
      - *Asabellides oculata*
      - *Ampharetidae*
    - F. Cirratulidae
      - *Caulleriella* sp. A
    - F. Dorvilleidae
      - *Parougia caeca*
    - F. Magelonidae
      - *Magelona* sp.
    - F. Maldanidae
      - Maldanidae
    - F. Nephtyidae
      - *Nephtys bucera*
    - F. Nereididae
      - *Neanthes arenaceodentata*
    - F. Opheliidae
      - *Ophelia denticulata*
      - *Travisia* sp. A
    - F. Paraonidae
      - *Aricidea* (*Acmira*) *cerrutii*
      - *Aricidea* (*Aricidea*) *wassi*
      - *Levinsenia* sp. A
      - *Paraonis fulgens*
      - *Paraonis pygoenigmatica*
    - F. Pectinariidae
      - *Pectinaria gouldii*
    - F. Phyllodocidae
      - *Eumida sanguinea*
      - *Paranaitis speciosa*
    - F. Polygordiidae
      - *Polygordius* sp.
    - F. Protodrilidae
      - *Protodriloides chaetifer*
    - F. Sigalionidae
      - *Sigalion arenicola*
      - Sigalionidae
    - F. Spionidae
      - *Polydora* sp.
      - *Scolelepis squamata*
      - *Spio setosa*
      - *Spiophanes bombyx*
    - F. Syllidae
      - *Streptosyllis arenae*
      - *Streptosyllis pettiboneae*
- P. Annelida
  - C. Oligochaeta
    - Oligochaeta
- P. Mollusca
  - C. Bivalvia
    - F. Donacidae
      - *Donax variabilis*
    - F. Mactridae
      - *Spisula solidissima*
    - F. Mytilidae
      - *Mytilus edulis*
    - F. Nuculidae
      - *Nucula annulata*
    - F. Pandoridae
      - *Pandora gouldiana*
    - F. Solenidae
      - *Ensis directus*
    - F. Tellinidae
      - *Tellina agilis*
    - F. Thraciidae
      - cf. *Bushia elegans*
  - C. Gastropoda
    - F. Calyptraeidae
      - *Crepidula plana*
      - *Crepidula* sp.
    - F. Nassariidae
      - *Nassarius trivittatus*
    - F. Pyramidellidae
      - Pyramidellidae
    - F. Turridae
      - *Kurtziella atrostyla*
- P. Arthropoda
  - C. Malacostraca
    - O. Amphipoda
      - F. Aoridae
        - *Pseudunciola obliquua*
        - *Unciola irrorata*
        - *Unciola* sp.
      - F. Caprellidae
        - *Aeginina longicornis*
      - F. Haustoriidae
        - *Acanthohaustorius millsi*
        - *Acanthohaustorius similis*
        - *Acanthohaustorius* spp.
        - *Bathyporeia parkeri*
        - *Parahaustorius attenuatus*
        - *Parahaustorius holmesi*
        - *Parahaustorius longimerus*
        - *Parahaustorius* spp.
        - *Protohaustorius wigleyi*
        - *Protohaustorius* sp.
        - *Pseudohaustorius borealis*

Table 4-3.
Delaware Coast Feasibility Study
Benthic Macroinvertebrate Taxa
Collected on Hen and Chickens
Shoal, 1993

BENTHIC MACROINVERTEBRATES*

- P. Arthropoda
  - C. Malacostraca
    - O. Amphipoda
      - F. Isaeidae
        - *Microprotopus raneyi*
      - F. Ischyroceridae
        - *Jassa marmorata*
      - F. Oedicerotidae
        - *Synchelidium americanum*
      - F. Phoxocephalidae
        - *Rhepoxynius hudsoni*
    - O. Cumacea
      - F. Bodotriidae
        - *Mancocuma stellifera*
        - *Pseudoleptocuma minor*
      - F. Diastylidae
        - *Oxyurostylis smithi*
    - O. Isopoda
      - F. Cirolanidae
        - *Politolana polita*
      - F. Idoteidae
        - *Chiridotea tuftsi*
      - F. Sphaeromatidae
        - *Ancinus depressus*
    - O. Mysidacea
      - F. Mysidae
        - *Neomysis americana*
    - O. Tanaidacea
      - F. Nototanaidae
        - *Tanaissus psammophilus*
    - O. Decapoda
      - InfraO. Anomura
        - F. Paguridae
          - *Pagurus longicarpus*
      - InfraO. Brachyura
        - F. Cancridae
          - *Cancer irroratus*
        - F. Pinnotheridae
          - *Dissodactylus mellitae*
        - F. Majidae
          - *Libinia emarginata*
      - InfraO. Caridea
        - F. Crangonidae
          - *Crangon septemspinosa*

- P. Echinodermata
  - C. Echinoidea
    - F. Echinarachniidae
      - *Echinarachnius parma*
    - F. Mellitidae
      - *Mellita quinquiesperforata*
    - Echinoidea

- P. Hemichordata
  - C. Enteropneusta
    - F. Harrimaniidae
      - *Saccoglossus kowalevskii*

- P. Chordata
  - SubP. Urochordata
    - C. Ascidiacea
      - F. Styelidae
        - *Cnemidocarpa mollis*
      - Ascidiacea
  - SubP. Cephalochordata
    - F. Branchiostomidae
      - *Branchiostoma caribaeum*

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* All samples combined, includes infauna and epifauna

Table 4-3 (continued).
Delaware Coast Feasibility Study
Benthic Macroinvertebrate Taxa
Collected on Hen and Chickens
Shoal, 1993

assessment on Hen and Chickens Shoal. The samples in the borrow site generally showed that mean organism density and mean number of taxa was intermediate between the control north and control south. These values were generally highest in control south and lowest in control north. The data suggested that the control south area had an overall greater species richness and diversity than those defined within the control north site. Based on this assessment, organism density, number of taxa, and wet weight biomass per unit area is generally lower compared to other offshore areas in the mid-Atlantic region. Mihursky et al. (1986) conducted a similar assessment off the Maryland coast from the Maryland/Delaware state line to the Ocean City Inlet. Here, the mean organism density and wet weight biomasses were significantly higher (460 individuals/0.1m^2 and 5.1 g/0.1m^2) than those determined by the Dames and Moore survey at Hen and Chickens Shoal (61 individuals/0.1m^2 and 0.84 g/m^2) (USFWS,1994). The benthic assemblage sampled within the borrow site on Hen and Chickens Shoal is consistent with high energy environments because of the low species diversity, low density of benthic macroinvertebrates, small individuals measuring < 2 cm, and biological communities of low biomass. The sampling recovered no commercially viable densities of commercial size shellfish or unique benthic assemblages within the study area (Dames and Moore, 1993). The entire benthic study on Hen and Chickens Shoal conducted by Dames and Moore report is presented in Appendix A of the Technical Appendices.

Subsequent to the 1993 benthic investigation of the borrow site, the Hen and Chickens Shoal borrow site had been expanded from 550 acres in size to 1,120 acres. This expansion includes the control south area on the southern part of Hen and Chickens Shoal. At the time of the benthic sampling, it was not known that there was abundant quantities of beach nourishment quality sand on this part of the shoal. It was recommended that after additional data was obtained from sediment analyses from vibracores, the borrow area should be expanded to include the southern part of the shoal. This expansion resulted in this area being utilized as a sand source for beachfill at Dewey Beach in 1994, which was conducted by the Delaware Department of Natural Resources and Environmental Control.

4.7.3.3 Fisheries

4.7.3.3.1 Shellfish

The surfclam has been periodically harvested from Delaware's coastal waters for commercial purposes. The surfclam has a wide distribution and abundance within the mid-Atlantic Region (Figure 4-5). They most commonly inhabit substrates composed of medium to coarse sand and gravel in turbulent waters just beyond the breaker zone (Fay et al., 1983; Ropes, 1980). The abundance of adults varies from loose, evenly distributed

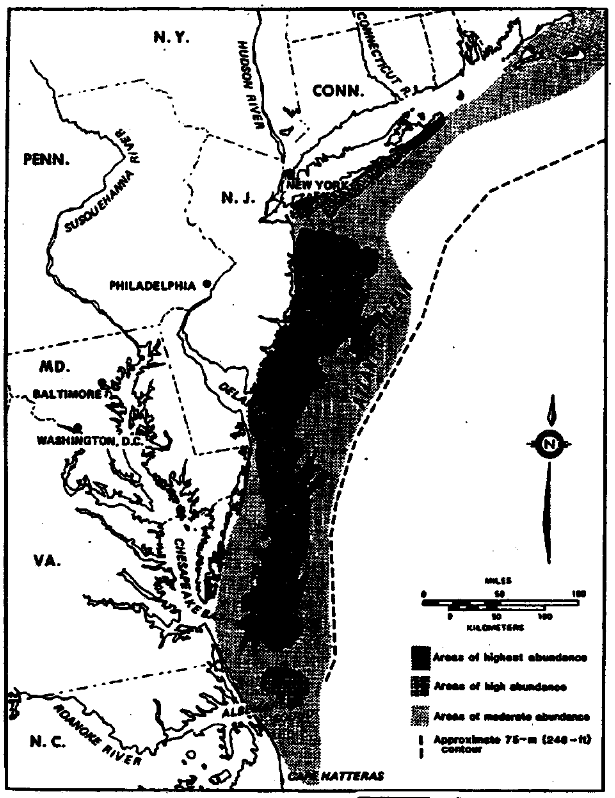

Figure 4-5.
Delaware Coast Feasibility Study
Distribution of Mid-Atlantic Surf
Clams Within the Mid-Atlantic
Bight (Fay et al., 1983)

aggregations to patchy, dense aggregations in the substrate (Fay et al., 1983). Surfclams may reach sexual maturity their first year, with the entire population being sexually mature during their second year (Mid Atlantic Fishery Management Council, letter dated 18 December 1995). Spawning may occur twice annually from mid-July to early August and from mid-October to early November.

A peak in harvesting within Delaware's coastal waters occurred in the early 1970's where annual landings exceeded 8.5 million pounds worth approximately $1.1 million. Shortly afterward, the stock experienced a rapid and severe decline, and by 1975, commercial harvesting had ceased. There has been no significant harvesting since then. The dominant 1976 year-class which supports New Jersey's inshore fishery, did not occur in Delaware waters. Surveys conducted by the State in 1982, 1986, and 1992 confirmed that no significant numbers of commercial sized surfclams exist within Delaware's three-mile territorial limit (Tinsman, 1993). Despite the lack of commercially harvestable densities of surfclams, juvenile forms of the surf-clams have been recorded in increasing densities on the Hen and Chickens Shoal in recent years. This has been confirmed by the recent benthic sampling conducted by Dames and Moore in 1993 which revealed that 75% of the samples contained specimens of juvenile surfclams. The maximum size surfclam collected was approximately 1.5 cm. Minimum size limits for harvestable surf-clams are set at 4.75 inches (approximately 120 mm), which is reached in 4-5 years (NOAA, letter dated 14 December 1995).

In addition to surfclams, the Delaware coastal area supports a small fishery for blue crabs (Callinectes sapidus), which are harvested in the winter by dredging. The fishery is usually limited to a few licenses to avoid over-harvesting this stock, which consists mainly of female crabs that would be spawning the following spring and summer. The major portion of the blue crab population remains in Delaware Bay.

4.7.3.3.2 Finfish

The proximity of several embayments allows the coastal waters of Delaware to have a productive fishery. Many species utilize the estuaries of Delaware Bay, Rehoboth Bay and Indian River Bay for forage and nursery grounds. The finfish found along the Delaware Atlantic coast are principally seasonal migrants. Winter is a time of low abundance and diversity as most species leave the area for warmer waters offshore and southward. During the spring, increasing numbers of fish are attracted to the Delaware Atlantic coast because of its proximity to several estuaries which are utilized by these fish for spawning and nurseries. Peaks in the numbers of fish species generally occur in the fall, however, Maurer et al. (1974) noted that fish abundance was greatest at Hen and Chickens Shoal during spring and summer, which indicates that Hen and Chickens Shoal is an important habitat or corridor to Delaware Bay for commercial and sport fish.

Surveys of the finfish in Delaware's coastal waters have been conducted by Maurer and Tinsman (1980), and annually for several years by the National Marine Fisheries Service. Abundant finfish species in Delaware coastal waters include: red hake (Urophycis chuss), northern sea robin (Prionotus carolinus), spot (Leiostomus xanthurus), windowpane flounder (Scopthalmus aquosus), silver hake (Merluccuns bilinearis), clearnose skate (Raja eglanteria), hogchoker (Trinectes maculatus), and weakfish (Cynoscion regalus). Large numbers of bay anchovies (Anchoa mitchilli), butterfish (Peprilus triacanthus), scup (Stenotomus chrysops), weakfish, striped anchovy (Anchoa hepsetus), spot, and bluefish (Pomatomus saltatrix) are also present in coastal waters. The complete list of fishes collected in these trawl surveys is shown in Table 4-4. These surveys, however, do not include habitats associated with any bottom structures like breakwaters, rock jetties and groins, rough bottom off of Cape Henlopen, submerged wrecks and artificial reefs. The following species are more associated with these structures: tautog (Tautoga onitis), gray triggerfish (Balistes capriscus), oyster toadfish (Opsanus tau), conger eel (Conger oceanicus), cunner (Tantogolabrus adspersus), and planehead filefish (Monacanthus hispidus) (Ekland, 1987).

The numbers of fishes along the Delaware Atlantic Coast are generally not sufficient to support a significant commercial fishing industry, however, the Delaware coast supports a diverse recreational fishery. Approximately 70% of Delaware's shore-based fishing is along the Atlantic coast beaches and jetties (Seagraves, 1988). There are also many private/charter boat fisherman from Indian River Inlet and Lewes that fish the coastal area. The species caught usually include: bluefish (Pomatomus saltatrix), weakfish (Cynoscion regalus), croaker (Micropogon undulatus), spot (Leiostomus xanthurus), kingfish (Menticirrhus saxatilus), red drum (Sciaenops ocellatus), tautog (Tautoga onitis), summer flounder (Paralichthys dentatus), striped bass (Morone saxatilus), scup (Stenotomus chrysops), sharks, hakes (Urophycis spp.), sea bass (Centropristis striata), Atlantic mackerel (Scomber scombrus) and Spanish mackerel (Scomberomorus maculatus). A sea bass pot fishery and early spring gill net fishing targeting shad and weakfish are the only prevalent commercial fishing operations in the coastal waters of Delaware.

4.7.4 Inland Bays

The Delaware coastal beaches are bordered on the west by three inland embayments: Rehoboth Bay, Indian River Bay, and Little Assawoman Bay. The inland bays are bordered extensively with tidal marshes composed of saltmarsh cordgrass (Spartina

Table 4-4. Fishes collected in Delaware Atlantic coastal waters

Common Name	Scientific Name
Red hake	Urophycis chuss
Northern sea robin	Prionotus carolinus
Spot	Leiostomus xanthurus
Windowpane	Scophthalmus aquosus
Silver hake	Merluccuns bilinearis
Clearnose skate	Raja eglanteria
Hogchoker	Trinectes maculatus
Weakfish	Cynoscion regalus
Butterfish	Peprilus triacanthus
Spotted hake	Urophycis regius
Little skate	Raja eglanteria
Striped sea robin	Prionotus evolans
Smooth dogfish	Mustelus canis
Summer flounder	Paralichthys dentatus
Spiny dogfish	Squalus acanthias
Atlantic menhaden	Brevoortia tyrannus
Bullnose ray	Myliobatis fremenvilli
Striped anchovy	Anchoa hepsetus
Ocean pout	Macrozoarces americanus
Scup	Stenotomus chrysops
Longhorn sculpin	Myoxocephalus octodecemspinosus
Atlantic herring	Clupea harengus
Atlantic croaker	Micropogon undulatus
Bluefish	Pomatomus saltatrix
Winter flounder	Pseudopleuronectes americanus
Striped bass	Morone saxatilus
American shad	Alosa sapidissima
Atlantic sturgeon	Acipenser oxyrhynchus
Striped burrfish	Chilomycterus schoepfi
Angel shark	Squatina dumerili
Northern stargazer	Astroscopus guttatus
Banded rudderfish	Seriola zonata
Bay anchovy	Anchoa mitchilli
Butterfish	Peprilus triacanthus
Blueback herring	Alosa aestivalis
American sand lance	Ammodytes americanus
Rough scad	Trachurus lathami
Alewife	Alosa pseudoharengus
Black sea bass	Centropristis striata
Atlantic silverside	Menidia menidia
Round herring	Etrumeus teres
Gulf stream flounder	Citharichthys arctifrons
Northern puffer	Sphoeroides maculatus

Table 4-4. Fishes collected in Delaware Atlantic coastal waters (continued)

Common Name	Scientific Name
Striped cusk-eel	Ophidion marginatum
Winter skate	Raja ocellata
Blue runner	Caranx crysos
Atlantic moonfish	Selene setapinnis
Inshore lizzardfish	Synodus foetens
Spanish mackerel	Scomberomorus maculatus
Smallmouth flounder	Etropus microstomus
Sandbar shark	Carcharhinus plumbeus
Unicorn filefish	Aluterus monoceros
Atlantic menhaden	Brevoortia tyrannus
Atlantic sharpnose shark	Rhizoprindon terraenovae
Roughtail stingray	Dasyatis centroura
Sea raven	Hemitripterus americanus
Pigfish	Orthopristis chrysoptera
Northern kingfish	Menticirrhus saxatilus
Short bigeye	Pristigenys alta
Dusky shark	Carcharhinus obscurus
Striped burrfish	Chilomycterus schoepfi
Banded rudderfish	Seriola zonata
Atlantic angel shark	Squatina dumerili
Blotched cusk-eel	Ophidion grayi
Thresher shark	Alopias vulpinus
Threespine stickleback	Gasterosteus aculeatus
Naked goby	Gobiosoma bosci

Source: Maurer and Tinsman (1980) and National Marine Fisheries Service Groundfish surveys from 1985-1989.

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alterniflora), saltmeadow hay (S. patens), spike grass (Distichlis spicata), and high tide bush (Iva frutescens) (Daiber et al.,1976). Rehoboth Bay is the nearest inland embayment to the project area and borders the barrier island on the west at the town of Dewey Beach. High development is present along the back-barrier of Dewey Beach, which was previously part of the tidal marsh complex that extends further south along Rehoboth Bay. Extensive tidal marshes are present along the western fringes of Rehoboth Bay. Rehoboth Bay has 48 miles of shoreline and a surface area of 14.8 square miles. Water depths at low tide are generally 7 feet or less. Saline water enters Rehoboth Bay from Indian River Bay and from the lower Delaware Bay through the Lewes-Rehoboth Canal. Due to differences in tidal marine and freshwater inputs, salinities vary throughout the bay on a daily, seasonal, and locational basis. Orris (1972) reported that salinities in Rehoboth Bay ranged from 20.1 to 30.6 ppt.

Common estuarine fishes present in the inland bays include: bay anchovy (Anchoa mitchilli), Atlantic silverside (Menidia menidia), mummichog (Fundulus heteroclitus), striped killifish (Fundulus majalis), naked goby (Gobiosoma bosci), and hogchoker (Trinectes maculatus). The inland bays are important nurseries for a variety of commercial and recreational fishes including: spot, croaker, weakfish, menhaden, bluefish, and summer flounder. Rehoboth bay supports sufficient numbers of hard clam (Mercenaria mercenaria) and blue crab (Callinectes sapidus) for recreational and/or commercial fisheries. The inland bays are also important for supporting a variety of waterfowl, shorebirds, and wading birds.

4.7.5 Freshwater Non-tidal Waterbodies

Three urbanized freshwater lakes are present within the vicinity of the project area. Lake Gerar in Rehoboth Beach receives drainage from nearby developments and is primarily surrounded by a thin buffer of maintained parkland and a relatively undeveloped woodlot on the west end. Silver Lake, between Rehoboth Beach and Dewey Beach, is the largest lake within the project area, and is surrounded by maintained lawns and residential development. Several stretches of emergent wetlands vegetated with common reed (Phragmites australis) are present along the shoreline. Silver Lake is notable for wintering waterfowl including Canada geese (Branta canadensis), mallard (Anas platyrhynchos), black duck (Anas rubripes) and canvasbacks (Aythya vallisineria). Fishery resource values of Silver Lake are described as relatively low (USFWS,1994). The eastern end of Silver Lake, until recently, was flanked by an undeveloped dune system. These dunes were breached by storm waves during the winter of 1993 introducing saline water into the lake.

Lake Comegys is also between Rehoboth Beach and Dewey Beach, however it is much smaller than Silver Lake. This lake lies west of Silver Lake Drive, and also is flanked by heavy residential development.

4.8 THREATENED AND ENDANGERED SPECIES

The only Federal or State listed endangered or threatened species known to occur near the project area on more than an occasional or transient basis is the piping plover (Charadrius melodus). These small shorebirds, which are classified as threatened on both the Federal and State lists, nest on coastal beaches and dunes. Most of Delaware's Atlantic beach and dune system, except in high development areas is potential nesting habitat. In recent years, piping plover have been nesting at

Cape Henlopen and Delaware Seashore State Parks. The nesting season usually begins in late March when the birds arrive and ends in July when the young are finally fledged. Shortly after hatching, the young leave the nest and begin foraging along the shoreline. The adults accompany the young during this critical period until they are fledged 25-35 days later. The State of Delaware has an active program to protect the bird's nesting activities. The program includes annual surveys to detect nesting birds and installation of fencing to close the nesting areas to intruders. The beaches and dunes within the confines of the Rehoboth/Dewey Beach study areas have not had any recent nesting sites for piping plovers (Ken Reynolds,personal communication).

The bald eagle (Haliaeetus leucocephalus) and peregrine falcon (Falco peregrinus anatum and F. p. tundrius) are other avian threatened and endangered species that may be present on only an occasional or transient basis.

The Delaware coast may be occasionally visited by five species of threatened and endangered sea turtles. These turtles include the loggerhead turtle (Caretta caretta), green turtle (Chelonia mydas), hawksbill turtle (Eretmochelys imbricata), Kemp's ridley turtle (Lepidochelys kempii) and leatherback turtle (Dermochelys coriacea). The loggerhead turtle and Kemp's ridley turtle are particularly more common in Delmarva coastal waters during summer months. Historically, the breeding range of the loggerhead turtle may have extended to the Delaware Atlantic Coast, however, there are no known nesting sites reported in this stretch of coast. The other four species breed much further south from Florida through the Caribbean and Gulf of Mexico. Overall, sea turtle utility of Delaware's twenty-five mile stretch of Atlantic Ocean presently or historically has not been significant. Sea turtles primarily utilize Delaware coastal waters as a transportation route from the Gulf Stream to Delaware Bay, where significant numbers have been observed utilizing the bay's resources as a feeding area (Logothetis,1994).

The only endangered fish that may be in the project area is the shortnose sturgeon (Acipenser brevirostrum). The shortnose sturgeon is an anadromous fish that primarily inhabits estuarine waters of the Delaware Bay and River. In the spring adults migrate from lower estuary and freshwater overwintering sites, upstream to upper tidal and lower non-tidal spawning grounds. In the fall, the bulk of the population migrates to the lower estuary to overwinter. The shortnose sturgeon is a benthic feeder and its diet is mainly composed of small worms and crustaceans.

Six species of endangered whales may occasionally be encountered in nearshore waters along the Delaware Atlantic Coast during their migrations. These include sperm whale (Physeter catodon), fin whale (Balaenoptera physalus), humpback whale (Megaptera novaeangliae), blue whale (Balaenoptera musculus), sei whale (Balaenoptera borealis) and black right whale (Balaena glacialis). The official list of threatened and endangered species in Delaware is in Table 4-5.

Two rare plant species, sea beach pigweed (Amaranthus pumilus) and chaffseed (Schwalbea americana), are found in beach and dune habitats in Delaware. There are no records of these species within the project area.

4.9 CULTURAL RESOURCES

In preparing the FEIS, the Corps has consulted with the Delaware State Historic Preservation Office (DESHPO) and other interested parties to identify and evaluate historic properties in order to fulfill its responsibilities under the National Historic Preservation Act of 1966, as amended, and its implementing regulations, 36 CFR Part 800. As part of this work, a remote sensing underwater investigation was conducted in the project borrow area. The final report of this study, entitled *Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island* (Cox, 1994) is included in Appendix A of the Main Report. The DESHPO has concurred with the District's finding that the project, as proposed, will have no adverse effect on significant cultural resources. Section 106 consultation with the DESHPO has been completed. Advisor Council on Historic Preservation (ACHP) notification of the District's "no adverse effect" finding is pending and will be completed prior to project construction. The following is taken largely from the above referenced report.

4.9.1 Prehistoric Resources

The prehistoric occupation of Delaware and the Delmarva Peninsula has been categorized by archaeologists into three general periods of cultural development: Paleo-Indian (15,000 years before present (B.P.) - 8,500 B.P.), Archaic (8,500 B.P. - 5,000 B.P.), and Woodland (5,000 B.P. - 400 B.P.). The Paleo-Indian period is the time of the earliest human occupation of theDelmarva Peninsula. Few Paleo-Indian sites have been located in Delaware. This is partly due to the low population density and nomadic lifestyle of the people from the period, as well as from the inundation of sites by sea level rise and burial under thick layers of alluvium and modern cultural deposits. The current Delaware coastline was covered by inland forests during the Paleo-Indian period, with tributary rivers flowing eastward towards the ancestral Delaware River. Paleo-Indian groups would have occupied coastal areas, but these geographic locations currently lie on the continental shelf and are submerged. Therefore, any evidence of Paleo-Indian occupation along the

Table 4-5. Official List of Endangered and Threatened Wildlife Species of Delaware[1]

Common Name	Scientific Name	Status
Delmarva Fox Squirrel	*Sciurus niger cinereus*	SE, FE
Sperm Whale	*Physeter catodon*	SE, FE
Blue Whale	*Balaenoptera musculus*	SE, FE
Finback Whale	*Balaenoptera physalus*	SE, FE
Sei Whale	*Balaenoptera borealis*	SE, FE
Humpback Whale	*Megaptera novaeangliae*	SE, FE
Right Whale	*Eubalaena spp.* (all species)	SE, FE
Hawksbill Sea Turtle	*Eretmochelys imbricata*	SE, FE
Leatherback Sea Turtle	*Dermochelys coriacea*	SE, FE
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	SE, FE
Tiger Salamander	*Ambystoma tigrinum*	SE
Bog Turtle	*Clemmys muhlenbergii*	SE
Cope's Gray Treefrog	*Hyla chrysoscelis*	SE
Barking Treefrog	*Hyla gratiosa*	SE
Bald Eagle	*Haliaeetus leucocephalus*	SE, FE
Peregrine Falcon	*Falco peregrinus*	SE, FE
Brown Pelican	*Pelecanus occidentalis*	SE
Shortnose Sturgeon	*Acipenser brevirostrum*	SE, FE
Piping Plover	*Charadrius melodus*	ST, FT
Green Turtle	*Chelonia mydas*	ST, FT
Loggerhead Turtle	*Caretta caretta*	ST, FT

KEY
FE- Federally Listed as "Endangered"
SE- State Listed as "Endangered"
FT- Federally Listed as "Threatened"
ST- State Listed as "Threatened"

[1] as of 2/25/94. List is slated for comprehensive review and revision
(Source: Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife)

Delaware Atlantic coastline would not directly relate to coastal environments but to exploitation of inland forest/riverine habitats. In Delaware, isolated fluted point finds and possible site locations appear to be related to lithic sources and areas favorable for hunting inland game near freshwater locations.

Archaic period peoples responded to the changed environmental conditions of the post-Pleistocene by exploiting a greater variety of resources. Archaeological investigations have shown that Archaic period sites tend to be relatively small, suggesting short-term and intermittent occupations in areas adjacent to interior freshwater swamps and bay/basin locations. Coastal tidal salt marshes and estuarine environments remained food resource-rich habitats available for exploitation. The prehistoric period that is best represented is the Woodland period, which is characterized by the introduction of pottery, increasing cultural diversity, and the evolution of a sedentary lifestyle that increasingly relied on agriculture. Woodland period culture remained intact until European contact. Woodland period sites have been identified on both the coastal marshes and in the mid-drainage areas in the region. Archaeological sites from this period produce distinctive ceramic forms and small triangular projectile points indicative of bow-and-arrow technology. Two prehistoric archaeological sites in the Rehoboth Beach area, the Warrington Site (7S-G-14) and Thompsons Island Site (7S-G-4), are listed on the National Register of Historic Places.

4.9.2 Historic Resources

The early history of the Delmarva Peninsula was marked by a succession of 16th and 17th century European expeditions such as those by Giovanni de Verrazano (1524), Estevan Gomez (1525), Henry Hudson (1609) and Cornelius Hendrickson (1614). European settlement in Delaware was initially focussed near Lewes. As early as 1622, a brick house was apparently in existence near the bay on Lewes Creek. In 1623, the Dutch East India Company constructed the first of several fortifications on the east shore of the bay. This was followed in the early 1630's by the creation of a Dutch patroonship, also centered in the vicinity of present day Lewes. A small whaling community known as "Zwaanendael" was established near Cape Henlopen in 1631 and abandoned a few years later due to local Indian conflict. The first Swedish expedition sailed into the Delaware in 1638 and established the region's first permanent European settlement at Wilmington, Delaware following the construction of Fort Christina. There appears to have been minimal European settlement activity along Delaware's Atlantic coastal area below Lewes in the first half of the 17th century.

The Dutch re-established control in the Lower Delaware in the early 1650's with the construction of Fort Casmir, on the site of present-day New Castle. "Zwaanendael" was re-colonized in 1658. However, the region remained strongly Swedish in a cultural sense as evidenced by a preference for log- constructed houses. The period of Dutch control was short-lived as the English took over all Dutch holdings in the Middle Atlantic region in 1664. For the entire later Colonial period, central and southern Delaware remained predominantly agricultural with dispersed farmsteads and a loosely defined road network. A "long lot" settlement pattern emphasized the importance of river and coastal transportation over roads. Two historic archaeological sites, the Avery Rest Site (7S-G-57) and Thompson's Loss and Gain Site (7S-G-60), and three historic properties, the Peter Marsh House, Dodd Homestead, and All Saints' Episcopal Church, in the Rehoboth Beach vicinity are listed on the National Register of Historic Places.

4.9.3 Maritime Resources

Although the Delaware Bay was visited by Henry Hudson in 1609 and explored by others within the next decade, the first comprehensive navigational chart of the Delaware Coast vicinity was not completed until 1776. In that year Joshua Fisher charted the waters of the Delaware Bay and provided the first bottom contours based on soundings. Privately published charts were available in the first half of the 19th century. However, standardized coastal charts were not initiated until the first United States Coast Survey was completed in the mid-19th century. In 1878, the United States Coast and Geodetic Survey began to periodically update the vicinity chart with detailed hydrographic information.

The earliest known aid to navigation in Delaware was the Cape Henlopen Light which was erected in 1767. A second light was constructed on Fenwick Island in 1858. Two breakwaters were constructed inside Cape Henlopen between 1869 and 1901. This "Harbor of Refuge" provided vessels protection from storms and ice. By the middle of the nineteenth century the U.S. Coast Guard had established a series of lifesaving stations at Lewes, Cape Henlopen, Rehoboth Beach, Indian River Inlet, Bethany Beach and Fenwick Island. Historic maritime activity within the project area was almost exclusively transient, with vessels crossing the area on coastal networks linking the Delaware River Ports and New York with other ports from Maine to Texas and the Caribbean to Central and South America. Over the years, many types of ships and vessels have wrecked while enroute up and down the coast. Many vessels were lost along the coast in an attempt to reach the Harbor of Refuge. Coastal storms, treacherous northeast winds and swift tidal currents coupled with historically heavy coastal traffic has caused the loss of dozens of documented sailing vessels, steamships, barges, tugs and large modern ships off the Delaware Coast. A variety of potential submerged cultural resource types in the project vicinity could date from the first half of the seventeenth century through the Second World War. The remote sensing investigation identified two magnetic targets exhibiting shipwreck characteristics. Remnants of a possible shipwreck or what could be the remains of a wood piling structural foundation are buried on the shoreline in front of the "Star of the Sea" building in Rehoboth Beach.

4.9.4 Submerged Prehistoric Sites

During the last glacial period, which terminated approximately 15,000 years ago, the sea level was 95 to 130 meters lower than current levels. The Delaware Atlantic shoreline at this time was on the edge of the modern continental shelf, some 50 to 60 kilometers of the present shoreline. According to area studies, the sea level rose at a steady pace between 7000 B.P. and 3000 B.P., with a slower rate of increase after ca. 3000 B.P. There is a possibility that prehistoric pleistocene landsurfaces are buried under shoaled offshore sand deposits at the borrow area.

4.10 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTES (HTRW)

A literature review was conducted within the study area to assess the potential of encountering any contamination associated with HTRW. This literature review utilized various databases from Delaware DNREC, the United States Environmental Protection Agency (USEPA), PCB-Waste Handlers (PADS), Small and Large Quantity Hazardous Waste Generators, and Treatment, Storage and Disposal of Hazardous Waste Facilities (HWDMS/RCRIS), National Priorities List (NPL), Facility Index System (FINDS) List, Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS), Radioactive Materials (MLTS), Release of Toxic Chemicals to Air, Water, and Land (TRIS), Manufacture or Importer of Toxic Substances (TSCA), Emergency Response Notification System (ERNS), Hazardous Materials Incident Report System (HMIRS), DE State Hazardous Waste Sites (SHWS), Leaking Underground Storage Tank Incidents (LUST), Registered Underground Storage Tank (UST), and Solid Waste Facility/Landfills (SWF/LS), and State Hazardous Waste Sites (SHWS). No sites were identified from this database inventory search.

The National Oceanic and Atmospheric Administration (NOAA) Cape Henlopen to Indian River Inlet Soundings Map indicates an area approximately three miles off the coast that has been designated a danger zone. Ocean-going vessels are permitted to navigate in this zone, however, all vessels are cautioned not to anchor, dredge, trawl, lay cable, or conduct any other activity that involves disturbing the substrate due to the potential danger from mines being buried within the substrate. The proposed sand borrow source is located outside of this area, and has been investigated by remote sensing magnetometer surveys during archaeological investigations. Two magnetic anomalies were recorded within the proposed borrow area.

Given the type of environmental settings within the study area and the associated land uses, the likelihood of encountering HTRW's is extremely low. No immediate concerns were identified from site visits, regulatory agency contacts, and database searches, therefore, any further HTRW investigations for the Rehoboth/Dewey Beach study area are not necessary.

4.11 SOCIO-ECONOMIC RESOURCES

Rehoboth Beach and Dewey Beach are located in Sussex County, Delaware, which is the largest yet least populated, with only 113,229 year round residents, totalling only 17% of the State's permanent population. The coastal study area is virtually devoid of manufacturing, relying almost 100% on the service/retail industry. Despite this dependency on the tourist industry, both Rehoboth Beach and Dewey Beach continue to display extremely low unemployment rates and high median household incomes. Rehoboth Beach is reported to have a low unemployment rate of 4.3% with a median income of $31,538. Dewey Beach has an almost unheard of unemployment rate of 0% and a median household income of $16,364.

Rehoboth Beach remains the most developed and heavily populated resort area on the Delaware Coast. The beach is lined with high-rise hotel and condominium complexes as well as the typical summer cottages. There are a total of 3,105 housing units within the town, of which only 21% are occupied year round. The median value of a single family home in 1990 was $205,000.

While there are only 1,234 year-round residents, Rehoboth Beach attracts thousands of summer residents every year with its beaches and its own boardwalk. The boardwalk contains all of the associated stores, fast food establishments, arcades and amusement rides. The town provides public access to the municipality's beach, and has many metered parking spaces along with various shuttle services. Still, parking may be difficult on weekends at the height of the tourist season as the population in Rehoboth soars to 110,000 on a holiday weekend.

The unincorporated area of Silver Lake is directly south of Rehoboth Beach. This area is designated in the Coastal Barrier Resources Act System. Presently, eleven houses are planned or being constructed between Silver Lake and the Atlantic Ocean.

Similar to Rehoboth Beach, the northern portion of Dewey Beach is backed by uplands, but the southern end of Dewey Beach differs greatly in its geography and vulnerability to storm damage. The southern end of Dewey Beach is situated on a narrow strip of land between the Atlantic Ocean and Rehoboth Bay. The town of Dewey Beach has become a developed overflow area of Rehoboth Beach, with additional public beach access. Dewey Beach is a changing community where older residences still exist. Over 41% of the population is retired and although more than half of the current residents have lived in their present homes for the past 15 years, things are starting to change. Many of the older properties are being sold, the cottages on them razed, and new modern townhouses built in their place. This is occurring in the southern part of town where it is zoned for multi-family dwellings, however the northern properties remain zoned for single family residences allowing some of the uniqueness to remain in the town.

5.0 ENVIRONMENTAL CONSEQUENCES

5.1 COMPARATIVE EFFECTS OF ALTERNATIVES

The no action alternative will allow the continuation of existing conditions as well as the existing processes which currently modify those conditions. Consequently, the following discussion will focus on the impacts of the beach nourishment alternative with impacts associated with the no action alternative discussed when appropriate. A brief summary comparing the effects of no action and beach nourishment alternatives is presented in Figure 3-1 (page 3-7).

5.2 TOPOGRAPHY AND SOILS

Under the no action alternative, erosion would continue and more beach would be lost. Without further engineering efforts, the existing bulkheads and erosion control measures would be rendered ineffective or breached as the beach profile became steeper and the wave energy became harsher.

The beach nourishment alternative would result in topography changes in the borrow source located on Hen and Chickens Shoal. The dredging would increase the depth by approximately 5 feet in the borrow site. This will result in a decrease in the average elevation from -35 feet NGVD to -40 feet NGVD, however, there may be some localized increases in dredging depth up to 15 feet depending on the quality of the material. Based on the quantities of material required, an area approximately 500 acres in size within the 1,120 acre sized borrow area will need to be utilized. The resulting cross-sectional configuration would be designed to approximate natural ridge slopes and therefore promote free exchange of water with the overlying and adjacent waters. The excavation would also be designed to ensure that all of the bottom substrate would not be removed and therefore the bottom would retain its existing substrate character. The intent of excavating a broad basin with depth, contours, and substrate consistent with the adjacent areas was to simulate the character of these nearby environments. It is not anticipated that the proposed excavation of material should adversely affect sand and gravel production.

Regarding the beach, the berm restoration would result in a berm 125 feet wide at Rehoboth Beach and 150 feet wide at Dewey Beach. Both areas would have a final berm elevation of +8 feet NGVD. A dune with an elevation of +14 feet and top width of 25 feet would be constructed along the entire project length (13,500 linear feet). The grade of the foreshore and underwater slopes would essentially parallel the existing profile. The increase in beach elevation would effectively widen the beach particularly in the southern end of the project. The beaches in the northern end of the project area would be affected to a much lesser degree because of the beach width already present and a tapered design profile. The net result would be a larger buffer against the erosion from storm events and also an increase in usable beach in the project area.

Results from coastwide acoustic subbottom profiling and vibracores indicate that one potential borrow area exists for the Rehoboth Beach/Dewey Beach area. This area contains large quantities of fine to medium sands, which were determined to be compatible beachfill based on the utilization of the U.S. Army Corps of Engineers Automated Coastal Engineering System. Consequently the substrate of the proposed beach should be similar in nature to the existing beach. Renourishment is not expected to be required more often than if native beach materials were used.

5.3 GROUNDWATER

For the beach nourishment alternative and all of its construction options, the effects of proposed construction and possible offshore borrow operation on the quality of production well water in the project area would be negligible. Most municipal and public water supply wells in the affected area draw from the Columbia (Pleistocene) Aquifer, which is between 10 feet and 180 feet thick (Miller, 1971). Hen and Chickens Shoal represents a hydrogeologic disconnection from the water supply aquifers. Based on the nature of fresh-saltwater interaction and the hydrogeologic disconnection of the borrow area, it is believed that the dredging on Hen and Chickens Shoal will have no impacts on the freshwater aquifers in the area.

5.4 HYDRODYNAMICS

The borrow area proposed for beach nourishment at Rehoboth Beach and Dewey Beach exists on the southern portion of Hen and Chickens Shoal. The borrow area lies due east from Rehoboth Beach and ranges between approximately 3,500 feet (northwest corner) to approximately 8,000 feet (southeast corner) offshore of the beaches. Based on the distance of the borrow area from the shoreline, quantities of material in the borrow area, and the rate of sedimentation in the shoal, it is concluded that initial beachfill and planned periodic nourishment will have negligible, if any, adverse effects on the physical or hydraulic characteristics of the adjacent shorelines.

5.5 WATER QUALITY

The dredging associated with the beach nourishment alternative would result in short-term adverse impacts to water quality in the immediate vicinity of the dredging and beach nourishment operations. Dredging in the proposed borrow area will generate turbidity resulting in sedimentation impacts within the immediate vicinity of the operations. Short-term increased turbidity can effect organisms in several ways. Primary production in phytoplankton and/or benthic algae may become inhibited from turbidity. Suspended particulate matter can clog gills and inhibit filter-feeding species. Reilly et.al. 1983 determined that high turbidity could inhibit recruitment by pelagic larval stocks. In addition, midwater nekton like finfish and mobile benthic invertebrates may migrate outside of the area where turbidity and deposition occur.

The amount of turbidity and its associated plume is mainly dependent on the grain size of the material. Generally, the larger the grain-size, the smaller the area of impact. The period of turbidity is also less with larger grain-sized materials. The proposed borrow location contains medium to fine sands, which are coarser grained than silts and clays. Turbidity resulting from the resuspension of these sediments is expected to be localized and temporary in nature. Utilization of a hydraulic dredge with a pipeline delivery system will help minimize the impact, however, some disturbance will occur.

Similar effects to water quality on aquatic organisms could likely be incurred from the deposition of borrow material on the beach. Increased turbidity resulting from the deposition of a slurry of sand will be temporary in nature and localized. This effect will not be significant as turbidity levels are naturally high in the high-energy surf zone. Organisms in the surf zone versus deep water areas will be less likely to suffer adverse effects from turbidity because they have already adapted to these conditions. Fine sediments winnowed from the deposited material are transported by waves and currents into the nearshore with varying environmental impacts from a few months to at least seven years (Hurme and Pullen, 1988). Parr et al, 1978 determined that fine materials were rapidly sorted out and transported offshore after beach deposition. In their study, the dredged material had a much higher silt content than the beach, however, all of the silt was removed within 5 months. The selection of borrow material from a high energy environment should minimize the fine particle content. Material taken from the Hen and Chickens Shoal borrow area will have low quantities of silt, therefore, high levels of turbid waters after deposition should not persist.

The borrow material is not expected to be chemically contaminated. The use of beach nourishment quality sand from a high energy environment coupled with the absence of nearby dumping activities, industrial outfalls, or contaminated water infers the low probability that the borrow material would be contaminated by pollutants (U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, 1991).

5.6 TERRESTRIAL ECOLOGY

5.6.1 Effects on Flora and Fauna of Upper Beach

Construction of the beach nourishment alternative would result in the initial placement of approximately 1.43 million cubic yards of sand on the beach with subsequent periodic nourishments of approximately 360,000 cubic yards every 3 years for a project life of 50 years. This construction will greatly disturb the impacted beach area, however, impacts to terrestrial species are expected to be minor and temporary. The existing species inhabiting the beach are generally capable of surviving adverse conditions, and most are capable of migrating out of the impacted area. Therefore, impacts are not expected to be significant. It would be reasonable to expect recolonization from adjacent areas shortly after the end of construction and a rapid return to pre-construction conditions.

5.7 AQUATIC ECOLOGY

5.7.1 Effects of Beachfill Placement on Benthos

The majority of the impacts of beachfill placement will be felt on organisms in the intertidal zone and nearshore zones. The nearshore and intertidal zone is highly dynamic, harsh, and is characterized by great variations in various abiotic factors. Approximately 136 acres of aquatic habitat (below mean high water) will be impacted by beachfill placement. This also includes approximately 11 acres of intertidal habitat to be affected by beachfill placement. Fauna of the intertidal zone is highly mobile and responds to stress by displaying large diurnal, tidal, and seasonal fluctuations in population density (Reilly et al. 1983). Despite the resiliency of intertidal benthic fauna, the initial effect of beachfill deposition will be the smothering and mortality of existing benthic organisms within the shallow nearshore (littoral) zone. This will initially reduce species diversity and number of animals. Burial of less mobile species such as amphipods and polychaete worms would result in losses, however, densities and biomasses of these organisms are relatively low on beaches. Beach nourishment may also inhibit the return of adult intertidal organisms from their nearshore-offshore overwintering refuges, cause reductions in organism densities on adjacent unnourished beaches, and inhibit pelagic larval recruitment efforts. Parr et al.1978 notes that the nearshore community is highly resilient to this type of disturbance, however, the offshore community is more susceptible to damage by receiving high sediment loads from fines sorting-out from a beachfill. The ability of a nourished area to recover depends heavily on the grain size compatibilities of material pumped on the beach (Parr et al.,1978). Reilly et al. 1978 concludes that nourishment initially destroys existing macrofauna, however, recovery is usually rapid after pumping operation ceases. Recovery of the macrofaunal component may occur within one or two seasons if grain sizes are compatible with the natural beach sediments. However, the benthic community may be somewhat different from the original community. Hurme et. al. 1988 caution, "Macrofauna recover quickly because of short life cycles, high reproductive potential, and planktonic recruitment from unaffected areas. However, the recolonization community may differ considerably from the original community. Recolonization depends on the availability of larvae, suitable conditions for settlement, and mortality. Once established, it may be difficult for the original community species to displace the new colonizers." Benthic recovery on the beach/intertidal zone may become hampered by the three-year periodic nourishments. Based on the above mentioned studies, the benthic community may take 1-2 years to recover. With a three-year renourishment cycle, the benthic community may be in a higher than normal state of flux due to periodic disturbances from re-nourishment. It is conceivable that the benthic community may attain a recovered state for a period of 1-2 years before being disturbed again by a re-nourishment cycle.

Grain size compatibility analyses conducted on sediments within the borrow site on Hen and Chickens Shoal indicate that there will be relatively low levels of fine sediments placed on the beach at Rehoboth Beach and Dewey Beach. Parr et.al. 1978 recommend that to minimize biological impacts, the percentage of fine sediments (smaller than 125 micrometers) should be low to minimize siltation and consequent deposition offshore, which may create anoxic conditions in the sediment. The berm restoration would be conducted in a manner that approximates the existing beach profile. The approximate area of intertidal and shallow nearshore habitat lost resulting from the beachfill would be likewise created seaward. Therefore, no significant loss of intertidal or shallow nearshore habitat is expected.

5.7.2 Effects on Benthos at Borrow Site

The primary ecological impact of dredging the sand borrow site will be the complete removal of the existing benthic community through entrainment into the dredge. It is estimated that approximately 1,120 acres of benthic habitat will be impacted by dredging during the project life. Dredging will primarily involve the immediate destruction of infaunal and some of the less mobile epifaunal organisms. Mortality of these organisms will occur as they pass through the dredge device and/or as a result of being transplanted into an unsuitable habitat. A secondary disturbance would be the generation of turbidity and deposition of sediments on the benthic community adjacent to the dredging. Despite the initial effects of dredging on the benthic community, recolonization is anticipated to occur within one year. Saloman et al. 1982 determined that short-term effects of dredging lasted about one year resulting in minor sedimentological changes, and a small decline in diversity and abundance within the benthic community. The recovery of a borrow area is dependent upon abiotic factors such as the depth of the borrow pits, and the rate of sedimentation in the borrow pits following the dredging. Dredging a borrow pit can result in changes that affect circulation patterns resulting in pits where fine sediments can become deposited, which may lead to hypoxia or anoxia in the pit. Accumulations of fine sediment may also shift a benthic community from predominantly a filter-feeding community to a deposit-feeding community. It is important that for recovery, the bottom sediments are composed of the same grain sizes as the pre-dredge bottom. Cutler et. al. 1982 investigated long-term effects of dredging on the benthic community and noted that faunal composition was different than the pre-dredge community, however, the difference was attributed more to normal seasonal and spatial variations. In this study, it was determined that there were no significant differences in the benthic communities and sediment parameters between borrow sites and surrounding areas. Periodic disturbances from maintenance of the project may favor the development of benthic communities composed primarily of colonizers. Assuming that the same location is dredged every three years, the secondary benthic community may be in a higher state of flux than the original community. This may, in effect, favor more r-selected (rapid reproduction, short life span) benthic species in the sand borrow impact area over the 50-year project life. In addition, benthic organism abundances may be lower than normal. However, this may not be the case if subsequent dredging cycles are conducted at different locations within the borrow area. This would allow disturbed areas from previous dredging disturbances to become recolonized.

Benthic investigations in and around the selected borrow site on Hen and Chickens Shoal indicate the presence of a benthic community that is low in abundances and diversity. The existing benthic community is adapted to dynamic conditions and is capable of rapidly recovering from such a disturbance (USFWS,1994). Recolonization of the benthic community may occur within 1-2 years following dredging, however, the effects of the three year periodic project maintenance over a 50 year project life may have more profound adverse effects if conducted at the same locations. Hurme et al. 1988 recommend that borrow materials be obtained from broad, shallow pits in nearshore waters with actively shifting bottoms, which would allow for sufficient surficial layer of similar sediments for recolonization. Measures that would minimize the effects of dredging in the borrow area include dredging in a manner as to avoid the creation of deep pits, alternating locations of periodic dredging, dredging during lowest biological activity, and the utilization of a hydraulic dredge with a pipeline delivery system to help minimize turbidity will be considered.

5.7.3 Effects of Groin Burial on Marine Biota

Groins, which represent artificial rocky intertidal habitat, will be subject to sand burial from beach nourishment. The landward ends of the groins would be permanently covered with sand. Once covered, the landward ends of the groins would not be available for fishermen to use nor to provide habitat for invertebrates, finfish, and shorebirds. Non-mobile organisms and intertidal dwellers would be affected by burial from the placement of sand. The fill placement over the groins is expected to re-establish sandy bottomed intertidal habitat.

5.7.4 Impacts on Fisheries

5.7.4.1 Shellfish

Since the 1970's, there have been no commercially harvestable stocks of surfclams within the Hen and Chickens Shoal proposed borrow area. For this reason, it can be expected that there will be no significant adverse impacts to this fishery from initial project construction. However, potential conflicts with periodic operation and maintenance of the project and the surf-clam fishery may arise during the 50 year life of the project. Hen and Chickens Shoal contains habitat suitable for surfclams and has supported extensive harvesting in the past (Tinsman,1993). Periodic dredging may have adverse impacts on a recovering surfclam fishery. Recent benthic studies indicate that there is a juvenile surfclam population on Hen and Chickens Shoal, however, these juveniles are not reaching commercial sizes and densities. Heavy predation on surfclams may be a contributing factor as to why they are not reaching large sizes (Dr. Hoff-MAFMC,personal communication). Despite the current conditions of the fishery, the potential for the surfclam fishery to recover and reach commercially harvestable sizes and densities does exist. Based on the rapid sexual maturity rates of surfclams, the juvenile clams found in the 1993 Dames and Moore survey may be contributing gametes and additional recruitment within the borrow area (Mid-Atlantic Fishery Management Council letter dated 18 Dec. 1995). Adverse impacts to a recovering surfclam population may be minimized by implementing a monitoring program for the subsequent periodic dredging in the borrow site. This monitoring may be necessary to determine if there is a commercially viable population of surfclams, and to locate areas within the proposed borrow site where surfclam densities are low enough to avoid the destruction of any significant stocks. Coordination with the appropriate resource agencies prior to periodic dredging for beach maintenance will be conducted to determine if and/or where surfclam monitoring is necessary.

5.7.4.2 Finfish

With the exception of some small finfish, most bottom and pelagic fishes are highly mobile and should be capable of avoiding entrainment into the dredging intake stream. It is anticipated that some finfish would avoid the turbidity plume while others may become attracted to the suspension of food materials in the water column. Little impacts to fish eggs and larvae are expected because these life stages are widespread throughout the Middle Atlantic Bight, and not particularly concentrated in the borrow site or surf zone of the project area (Grosslein and Azarovitz, 1982).

The primary impact to fisheries will be felt from the immediate loss of a food source by disturbing benthic macroinvertebrate communities. Demersal finfish feed heavily on bottom dwelling species, thus, the loss of benthos and epibenthos entrained or smothered during the project will temporarily disrupt the food chain in the impact area. This effect is expected to be temporary as these areas become rapidly recolonized by infaunal and epifaunal macroinvertebrates.

5.8 THREATENED AND ENDANGERED SPECIES

The piping plover, which is State and Federally listed as threatened, is an inhabitant of Delaware's sandy beaches. Nesting sites of this species have been primarily limited to Cape Henlopen State Park and Delaware Seashore State Park. No known nesting sites have been identified within the study area of Rehoboth Beach and Dewey Beach (Reynolds,1995). Based on the high development and human disturbance, it is unlikely for piping plovers to nest within the project area. However, if a piping plover nest is discovered within the project area prior to the commencement of the initial beach nourishment and periodic maintenance activities, the Corps will contact the Delaware Department of Natural Resources and Environmental Control Division of Fish and Wildlife and the U.S. Fish and Wildlife Service to determine appropriate measures to protect the piping plovers from being disturbed. These measures may include establishing a buffer zone around the nest and limiting construction to be conducted outside of the nesting period (1 April - 1 September).

From June through November, Delaware's coastal waters may be inhabited by transient sea turtles, especially the loggerhead (Federally listed threatened) or the Kemp's ridley (Federally listed endangered). Sea turtles have been known to be adversely impacted during dredging operations that have utilized a hopper dredge. Dredging encounters with sea turtles have been more prevalent along waters of the southern Atlantic and Gulf coasts, however, incidences of "taking" sea turtles have been increasing in waters of the middle Atlantic coast. Coordination with the National Marine Fisheries Service (NMFS) in accordance with Section 7 of the Endangered Species Act has been undertaken on all Philadelphia District Corps of Engineers dredging projects that may have impacts to Federally threatened or endangered species. A Biological Assessment that discusses Philadelphia District hopper dredging activities and potential effects on Federally threatened or endangered species of sea turtles has been prepared, and was formally submitted to NMFS in accordance with Section 7 of the Endangered Species Act. A Biological Opinion from NMFS is still pending upon final review of the Biological Assessment. Adherence to the findings of the Biological Opinion will insure compliance with Section 7 of the Endangered Species Act. In the interim, measures to reduce the likelihood of disturbing or taking of these species would be implemented through coordination with the NMFS. Recent projects that have utilized a hopper dredge between June and November have been required to place NMFS approved sea turtle observers on the dredge to monitor for sea turtles during dredging. During July - August, 1994, DNREC conducted beach nourishment activities at Dewey Beach, Bethany Beach and South Bethany Beach where a turtle observer was required to be on the dredge for at least 25% of the operations. Observers inspected the hopper, skimmer, and draghead after each load. Additional observations of the hopper were made during pump-out operations due to improved visibility. Logothetis (1994) reported that there was "no tangible evidence that any sea turtles were harassed, injured or terminated during the monitoring periods of the dredging operations".

5.9 IMPACTS ON CULTURAL RESOURCES

5.9.1 Project Impact Areas for Cultural Resource Review

Proposed project construction has the potential to impact cultural resources in three areas. These are the existing beach, the near-shore sand placement area, and the offshore borrow area. In the existing beach and near-shore sand placement areas, potential impacts to cultural resources could be associated with the placement and compaction of sand during berm and dune construction. Sand dredging activities in the offshore borrow area could impact historic properties.

5.9.2 Impacts to Cultural Resources

On the basis of the current project plan, the Corps is of the opinion that this project will have no adverse effect on significant cultural resources in onshore beach and near-shore underwater project areas. These two areas are located in a highly unstable and shifting coastal environment where the likelihood for intact and undisturbed cultural resources is considered extremely minimal. A review of site records and historic maps indicates a low probability for historic structural remains in the project beach area. The shipwreck remnants buried in front of the "Star of the Sea" building in Rehoboth Beach do not exhibit integrity or historical significance. For these reasons the Corps did not conduct a pedestrian onshore cultural resource survey of the project area. In addition, a remote sensing survey was not conducted in the underwater near-shore project area due to unsafe conditions in the very high energy tidal surf zone. The seven properties in the Rehoboth Beach area currently listed on the National Register of Historic Places are located outside of the project area and will not be impacted by proposed construction.

5.9.3 Offshore Borrow Area

The remote sensing investigation of the borrow area identified two relatively small magnetic targets exhibiting shipwreck characteristics. These targets may be associated with one vessel. Proposed sand borrowing activities will adversely impact these target locations, which may represent a significant cultural resource. Therefore, in order to eliminate construction impacts at these locations, the Philadelphia District proposes to completely avoid these two remote sensing targets during sand borrowing operations by delineating at least a 200 foot buffer around each target.

Vibracore samples taken from the borrow area to a depth of 20 feet below the ocean floor indicate a series of shoaled sand deposits with no substantial clay or organic layers indicating buried pleistocene landsurfaces. As currently planned, the dredging depth of the borrow area over the life of the project will not exceed this 20 foot depth.

5.9.4 Section 106 Coordination

The report of the remote sensing investigation, entitled *Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island* (Cox, 1994), was submitted to the Delaware State Historic Preservation Office (DESHPO) for Section 106 review and comment on February 14, 1994 (see Appendix A of Main Report). The DESHPO concurred with the report's recommendation to avoid borrow area target locations in a letter dated December 1, 1994.

Based on a review of project documentation and the cultural resources investigation report, the District found that the project plan, as proposed, will have no adverse effect on significant cultural resources. The DESHPO concurred with the District's "No Adverse Effect" finding in a letter dated January 11, 1996 (see Appendix A of Main Report). DESHPO Section 106 consultation for the project has been completed. ACHP notification of the District's "No Adverse Effect" finding is pending and will be completed prior to project construction.

5.10 IMPACTS ON NOISE AND AIR QUALITY

Minor short-term impacts to air quality and noise levels would result from the construction phases of the beach nourishment alternative. Dredging activities and grading equipment use would produce noise levels in the 70 to 90 dBA (50 feet from the source) range but these would be restricted to the beach area. These noises would be masked by the high background levels of the surf or dissipated by distance. Ambient air quality would also be temporarily degraded, but emission controls and limited duration aid in minimizing the effects. In the case of equipment use associated with the periodic nourishment efforts, conducting the work in the off-season would further minimize the impact.

Noise and air quality impacts would be restricted to site construction preparation (generally beginning two weeks prior to dredging) and the actual dredging and placement operation. Noise is limited to the utilization of heavy equipment such as bulldozers to manipulate the material during placement. Additional noise may be caused by a pumpout station, if necessary. Depending on future circumstances, the construction may be conducted overnight to meet construction schedules. Both municipalities of Dewey Beach and Rehoboth Beach have restrictive noise ordinances, however, local officials have indicated that construction activities such as this project would be exempt from noise ordinances.

Air quality impacts would similarly be limited to emissions from the heavy equipment and pumpout station (if used). Pollutant emissions discharged from heavy equipment such as dredges and dozers are regulated by the EPA on the engine manufacturers. Since dredging operations would be conducted in a "marginal" non-attainment area for ozone, equipment operations would not have any long-term adverse effects on the attainment criteria in Sussex County. Dredging and its associated construction activities is considered to be a temporary mobile operation not requiring an air quality permit from the State to be in compliance with the State Implementation Plan (Personal communication with Mr. John Thomas-DNREC Air Quality Management Section). The Environmental Protection Agency Region III had reviewed the Draft EIS, and had no adverse comments relative to air quality impacts pursuant to Section 309 of the Clean Air Act. A statement of conformity with the State Implementation Plan is provided on page 9-1 of this document.

5.11 IMPACTS ON SOCIO-ECONOMICS

The no action alternative would allow the beach to continue to erode, and this would increase the risk of damage to private property from flooding or direct wave action as the protective to erode, and this would increase the risk of damage to private property from flooding or direct wave action as the protective beach decreased in size. Property values would also fall as this risk became more and more perceived by the market. Recreational opportunities would also decrease with the size of the beach. This would be translated into lost tourism revenue which would have a secondary effect on employment.

Delaware beaches are consistently the number one travel destination in Delaware, and account for half of the State's visitations. It is expected that local and State efforts to attract visitation and expand their associated facilities will continue. The Delaware beaches play an extremely significant role in the well being of Delaware's tourism industry and in Delaware's overall economy.

Under the beach nourishment alternative, the beach berm created by the placement of suitable material and periodic nourishment would permit the accommodation of both present and expected future demands for recreational beach area along Dewey Beach and Rehoboth Beach. This influx of seasonal population is reflected by a greater demand for social services such as housing, transportation, health, safety, and sanitation facilities. Dewey Beach and Rehoboth Beach are supported by a tourist economy which they cannot afford to lose, and their expansion would provide fuller employment and greater revenues. As the demand for recreation gradually increases, it is expected that State and local efforts would be made to satisfy these needs. Because of this, noise and air quality levels would similarly degrade through personal activity and auto utilization. They will not however, become a significant problem.

Various indicators of the presence and/or level of Corps activity in beachfront communities generally have no statistically significant relation to development in those areas. Thus, the statistical evidence indicates that the effect of the Corps on induced development is, at most, insignificant, compared to the general forces of economic growth which are stimulating development in these areas, many of which are induced through other municipal infrastructure developments such as roads, wastewater treatment facilities, etc. (U.S. Army Corps of Engineers, 1995).

5.12 RECREATION AND BEACH ACCESS

The proposed project as a secondary benefit, may improve opportunities for recreational beach use. Recreational shore and surf fishing will be temporarily affected by the project, since the public and fishermen will not be permitted to enter the actual work segments. However, since the project will be constructed in sections, only those sections actually under construction will be closed to the public. Impacts to shore and surf fishing access will be localized and relatively short-lived. A minor impact on recreational fishing will result from covering the existing groins with sand.

The proposed project will not impede public access to the beach. Public access to the beaches in Rehoboth Beach and Dewey Beach would be maintained by the construction of 39 dune walkovers. Two vehicle access ramps would be provided to allow for beach access for authorized vehicles.

5.13 AESTHETICS

Beach nourishment is a more natural and soft structural solution to reducing storm damages in Rehoboth Beach and Dewey Beach. With the exception of short-term impacts during construction, overall aesthetics of the beach would be improved as a result. A natural-looking beach and dune would be more aesthetically pleasing and attractive to residents and tourists. Despite the visual benefits the beach nourishment alternative would provide, a restored dune may inhibit ocean views in some project impact areas. Obstruction of an ocean view is likely to occur from ground level, thus areas that do not have raised structures (higher than the proposed dune elevation of +14 feet NGVD) would lose an ocean view. Along one section of the boardwalk in Rehoboth Beach, the proposed dune would be approximately one foot higher than the top surface of the boardwalk, however, this would not be high enough to produce visual obstructions of the beach and ocean when viewed from the boardwalk.

5.14 UNAVIODABLE ADVERSE IMPACTS

The long-term adverse impact of the no action alternative would not be to the natural environment but to the regional economic environment. Tourism and utilization would decrease as beach loss continues. As the risk of storm damage increases, property values would decrease. Actual storm damage and higher insurance premiums would erode business profits.

The long-term adverse impact of the beach nourishment alternative would be the decreased benthic community standing stocks, which would be affected during each dredging operation.

5.15 SHORT-TERM USES OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

The no action alternative does not involve short-term uses but would affect the long-term economy of the project area as indicated in Section 5.11. On the other hand, the beach nourishment alternative would enhance the economy by storm damage reduction as well as by providing additional recreational area.

5.16 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The no action alternative does not involve a commitment of resources. The beach nourishment alternative would involve the utilization of time and fossil fuels which are irreversible and irretrievable. Impacts to the benthic community would not be irreversible as benthic communities would redevelop with cessation of all dredging activity.

5.17 CUMULATIVE EFFECTS

Cumulative Impact as defined in CEQ regulations is the "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Projects of this nature using beach nourishment from an offshore borrow site are becoming increasingly common in coastal areas as areas of high development become susceptible to the erosive forces present. Numerous beach nourishment projects have been conducted along the Atlantic Coast since the 1960's by local, State and Federal agencies as well as private interests. Depending on circumstances such as the methods being utilized to alleviate the coastal erosion and ensuing storm damages and the existing ecological and socio-economic conditions, it is difficult to gauge the net cumulative effects of these actions. The scientific literature generally supports that beach nourishment projects, if planned properly, have short-term and minor ecological effects, however, we are not aware of any studies that consider regional or national cumulative impacts of these projects on resources of concern. It is our position that since this project was designed to minimize adverse environmental effects of all types, this project should not culminate in adverse cumulative impacts on ecological and socio-economic resources, or if it does, to the minimum extent possible.

5.18 MITIGATION MEASURES

Mitigation measures are utilized to minimize or mitigate for project impacts to environmental resources within the project area. The appropriate application of mitigation is to formulate a project that avoids or minimizes adverse impacts first, and compensates for impacts only as a final alternative. Several measures can be adopted to avoid or minimize project impacts on effected resources such as: benthic resources, fisheries, endangered species, cultural resources, recreation, and noise.

Mitigation measures are either institutional in that environmental mitigation is inherent in project alternative selection, or as measures incorporated into the construction and operation and maintenance of the project. Several institutional measures have already been adopted to minimize the impacts on these resources. These measures include the selection of the beach nourishment alternative. This alternative offers a more naturalistic and softer approach for storm damage reduction. Selection of this alternative is based on its relatively low ecological impacts and its cost effectiveness. Another institutional measure is the utilization of an offshore sand borrow area. This area is characterized by high energy and shifting sands resulting in a benthic community of lower abundance and diversity as compared to more stable benthic environments. Therefore, ecological impacts are expected to be lower. Another measure is the selected use of suitable sand grain sizes for beach nourishment. The selection of the borrow area is based on compatibility studies for sand grain sizes. The selection of coarser beach nourishment quality material will minimize impacts on water quality at the dredging site and discharge (placement) site.

The identification of two small magnetic targets within the proposed sand borrow area exhibiting shipwreck characteristics will be avoided during project construction. This will be accomplished by delineating at least a 200 foot buffer around each target.

As discussed in the preceding paragraphs, the beach nourishment alternative does contain unavoidable impacts to several environmental resources of concern. These impacts can be minimized by implementing several measures during construction, and operation and maintenance of the project. Mitigation measures recommended for construction, and operation and maintenance of the project involve minimizing impacts to: benthic resources, fisheries, endangered species, recreation and noise. The following measures are recommended, however, their implementation is dependent upon the circumstances that may be encountered at the time of project construction or periodic maintenance.

5.18.1 Benthic Resources

The majority of unavoidable impacts are likely to be incurred on the benthic communities within the project area. Measures to minimize the effects of dredging in the borrow area will include dredging in a manner as to avoid the creation of deep pits, alternating locations of periodic dredging, conducting dredging during months of lowest biological activity (when possible), and the utilization of a pipeline delivery system to help minimize turbidity. Implementation of a benthic monitoring program concurrent with periodic maintenance activities would document project impacts and aid in avoiding impacts to sensitive areas during the periodic maintenance activities.

5.18.2 Fisheries

Adverse impacts to a potentially recovering surfclam population may be minimized by implementing a monitoring program for the subsequent periodic dredging in the borrow site. This monitoring may be necessary to determine if there is a commercially viable population of surfclams, and to locate areas within the proposed borrow site where surfclam densities are low enough to avoid the destruction of any significant stocks. Coordination with the appropriate resource agencies prior to periodic dredging for beach maintenance will be conducted to determine if and/or where surfclam monitoring is necessary.

5.18.3 Threatened and Endangered Species

Based on coordination with appropriate resource agencies and the high development in the project impact site, it is unlikely for piping plovers to nest within the project area. However, if a piping plover nest is discovered within the project area prior to the commencement of the initial beach nourishment and periodic maintenance activities, the Corps will contact the Delaware Department of Natural Resources and Environmental Control Division of Fish and Wildlife and the U.S. Fish and Wildlife Service to determine appropriate measures to protect the piping plovers from being disturbed. These measures may include establishing a buffer zone around the nest and limiting construction in these areas to periods outside of the nesting season (1 April - 1 September).

Depending on the timing of the dredging and the type of dredge to be used, it may be necessary to implement mitigative measures to avoid adversely impacting threatened or endangered sea turtles. If a hopper dredge (with suction head) is used, measures to avoid or minimize impacts to these species may include but not be limited to utilizing NMFS approved turtle monitors, utilizing specially modified hopper dredges, and use of trawlers that can intercept and transport turtles away from the dredging impact area. It may not be necessary to implement these measures if dredging is conducted within the winter months when turtle activity is lowest in this area. These measures would be implemented based on the findings of the forthcoming Biological Opinion to be issued by NMFS.

5.18.4 Recreation

Beachfill operations typically occur within isolated segments, subsequently moving as the work progresses. As each work segment is completed, it can be opened for recreational use. This would allow access for recreation in all areas outside of the segment under construction.

5.18.5 Air Quality and Noise

Air quality and noise impacts can be reduced by utilizing heavy machinery fitted with approved muffling apparatus that reduces noise, vibration, and emissions. Construction activities can be scheduled for normal daytime hours to further reduce noise impacts to the surrounding communities.

6.0 LIST OF PREPARERS

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The following individuals were primarily responsible for the preparation of this Environmental Impact Statement.

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6.2 Studies Conducted for or Reported in this Final Environmental Impact Statement

6.2.1 Benthic Evaluation

"Benthic Animal- Sediment Assessment of Potential Beachfill Borrow Source For The Rehoboth/Dewey Beach, Delaware Interim Feasibility Study" (Dames & Moore, 1993) in Appendix A of the Technical Appendices.

6.2.2 Cultural Resources

"Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island" (Cox, 1994) in Appendix A of the Technical Appendices.

7.0 PUBLIC INVOLVEMENT

A notice of intent to prepare a Draft Environmental Impact Statement (DEIS) for the Rehoboth Beach and Dewey Beach Storm Damage Reduction Project was published in the Federal Register on 14 October 1994. Several coordination/scoping meetings were held with Federal, State and local resource agencies. Agencies notified of this study included the U.S. Fish and Wildlife Service (USFWS), U.S. Environmental Protection Agency (USEPA), National Marine Fisheries Service (NMFS), Delaware Department of Natural Resources and Environmental Control (DNREC), Delaware State Historic Preservation Office, City of Rehoboth Beach, and Town of Dewey Beach. Information in this document was generated based on comments and concerns of the interested public.

Information generated during this study (Delaware Coast - Cape Henlopen to Fenwick Island Feasibility Study) was subsequently utilized by the Delaware Department of Natural Resources and Environmental Control to obtain a Department of the Army Permit for an emergency beachfill at Dewey Beach in the summer of 1994 to discharge 600,000 cubic yards of sand into waters of the United States. Prior to the issuance of the Department of the Army Permit, several resource agencies including the U.S. Army Corps of Engineers, USFWS, USEPA Region III, NMFS, DNREC, and DESHPO reviewed the permit application utilizing the information generated during this study.

Two Planning Aid Reports prepared by the USFWS are provided in the pertinent correspondence section of the main report. An official section 2(b) Fish and Wildlife Coordination Act Report was prepared by the USFWS after public circulation of the Draft Environmental Impact Statement and is provided in the comment/response section. This report provides official USFWS comments on the project pursuant to the Fish and Wildlife Coordination Act. Comments received from Federal, State, and local government agencies along with various private organizations and individuals on the DEIS are presented in the comment/response section in the rear of the main report.

A copy of the DEIS along with this FEIS were provided to the following individuals/agencies for review:

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8.0 EVALUATION OF 404(b)(1) GUIDELINES

I. PROJECT DESCRIPTION

A. Location

The proposed project site is in the vicinity of Rehoboth Beach and Dewey Beach, Sussex County, Delaware. The specific areas involved are Hen and Chickens Shoal and the nearshore area of Rehoboth Beach and Dewey Beach.

B. General Description

The proposed project involves reducing potential storm damages at Rehoboth Beach and Dewey Beach, Delaware by placement of dredged material (sand) from Hen and Chickens Shoal on the beachfront in the form of a berm 125 feet wide at an elevation of +8 feet NGVD in Rehoboth Beach and a berm of 150 feet in width at an elevation of +8 feet NGVD in Dewey Beach. A dune is proposed along the entire length with a top elevation of +14 feet NGVD and a top width of 25 feet. The total length of berm and dune restoration is approximately 13,500 linear feet.

C. Authority and Purpose

The authority for the proposed project is the resolution of the Committee on Environment and Public Works of the United States Senate dated 23 June 1988. This resolution reads as follows:

> "RESOLVED BY THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS OF THE UNITED STATES SENATE, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby requested to review the report on the Delaware Coast from Kitts Hummock to Fenwick Island, Delaware, published as House Document Number 85-216, and other reports, with a view to determining the advisability of providing improvements in the interest of beach erosion control, hurricane protection, and related purposes, along the Delaware Coast from Cape Henlopen to Fenwick Island. Included in this study will be the development of a physical and engineering data base on coastal area changes and processes, including appropriate monitoring during development of the data base, as the basis for actions to prevent the harmful effects of shoreline erosion and storm damage."

The purpose of the project is to reduce storm damages to the beaches and oceanfront structures of Rehoboth Beach and Dewey Beach, Sussex County, Delaware.

D. General Description of Dredged or Fill Material

1. The proposed dredged material is medium to fine sand with little or no gravel present. Clay, silt, and organic content are low with neutral pH and low fertility. This material has been trapped by a combination of tidal and littoral forces and has been exposed to a high energy circulation regime.

2. The quantity required is estimated to be approximately 1.43 million cubic yards initially with approximately 360,000 cubic yards every 3 years comprising periodic nourishment over a 50-year project life.

3. The proposed source of the borrow material is on Hen and Chickens Shoal located just east of Cape Henlopen in a NNW-SSE orientation. The shoal is formed and maintained by ebb tide currents depositing medium and fine sand from Delaware Bay. The size of the borrow area is approximately 1,120 acres. The average depth within the borrow area is - -35 feet NGVD. Dredging would occur to approximately -40 feet NGVD which would approximate the normal depth contours in the areas adjacent to the ebb shoal.

E. Description of the Proposed Discharge Site

1. The proposed location is depicted in Figures 3-1 through 3-4 of the FEIS.

2. The proposed discharge is comprised of an eroding berm approximately 13,500 feet long with a minimum design width of 125 feet in Rehoboth Beach and 150 feet in Dewey Beach. The total area impacted below mean high water is approximately 136 acres. The total intertidal area impacted is approximately 11 acres.

3. The proposed discharge site is unconfined with placement to occur on a shoreline area.

4. The type of habitat present at the proposed location is a coastal intertidal and nearshore habitat.

5. Berm and Dune restoration will be accomplished by beach nourishment. This plan will require approximately 1.43 million cubic yards of sand for initial beachfill placement with approximately 360,000 cubic yards for periodic re-nourishments every 3 years over a 50 year project life. The proposed plan includes approximately 13,500 linear feet of beachfill extending from the northern end of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach. The beach tapers into the existing shoreline in the north end at

Deauville and in the southern end at North Indian Beach. This will result in a 125 foot wide berm at an elevation of +8 feet NGVD in Rehoboth Beach and a 150 foot wide berm at an elevation of +8 feet NGVD in Dewey Beach. A dune is proposed along the entire length and on top of the berms in both communities with a top elevation of +14 feet NGVD and a top width of 25 feet.

6. Initial construction would result in the placement of approximately 33,048 cubic yards of sand at Rehoboth Beach and 105,780 cubic yards of sand at Dewey Beach between Mean High Water and Mean Low Water (Intertidal Zone). Approximately 216,649 cubic yards of sand at Rehoboth Beach and 791,023 cubic yards of sand at Dewey Beach would be placed below Mean Low Water during initial construction.

F. Description of Disposal Method

A hydraulic dredge or hopper dredge would be used to excavate the borrow material from the borrow area. The material would be transported using a pipeline delivery system to the beachfill placement site. Subsequently, final grading would be accomplished using standard construction equipment.

II. FACTUAL DETERMINATION

A. Physical Substrate Determinations

1. The final proposed elevation of the beach substrate after fill placement would be +8 feet NGVD at the top of the berm. The proposed profile would have a foreshore slope of 15H:1V and an underwater slope that parallels the existing bottom to the depth of closure.

2. The sediment type involved would be sand.

3. The planned construction would establish a construction template which is higher than the final intended design template or profile. It is expected that compaction and erosion would be the primary processes resulting in the change to the design template. Also, the loss of fine grain material into the water column would occur during the initial settlement.

4. The proposed construction would result in removal of the benthic community from the borrow area, and burial of the existing beach and nearshore benthic communities when this material is put in place during berm construction.

5. Other effects would include a temporary increase in

suspended sediment load and a change in the beach profile, particularly in reference to elevation.

6. Actions taken to minimize impacts include selection of fill material that is similar in nature to the pre-existing substrate. Also, standard construction practices to minimize turbidity and erosion would be employed.

B. Water Circulation, Fluctuation, and Salinity Determinations

1. Water. Consider effects on:

   a. Salinity - No effect.
   b. Water chemistry - No significant effect.
   c. Clarity - Minor short-term increase in turbidity during construction.
   d. Color - No effect.
   e. Odor - No effect.
   f. Taste - No effect.
   g. Dissolved gas levels - No significant effect.
   h. Nutrients - Minor effect.
   i. Eutrophication - No effect.
   j. Others as appropriate - None.

2. Current patterns and circulation

   a. Current patterns and flow - Circulation would only be impacted by the proposed work in the immediate vicinity of the borrow area, and in the beach zone where the existing circulation pattern would be offset seaward the width of the beach nourishment.

   b. Velocity - No effects on tidal velocity and longshore current velocity regimes.

   c. Stratification - Thermal stratification occurs beyond the mixing region created by the surf zone. There is a potential for both winter and summer stratification. The normal pattern should continue after construction of the proposed project.

   d. Hydrologic regime - The regime is largely marine and oceanic. This will remain the case following construction of the proposed project.

3. Normal water level fluctuations - The tides are

semidiurnal with a mean tide range of 3.9 feet and a spring tide range of 4.7 feet in the ocean. Construction of the proposed work would not affect the tidal regime.

4. Salinity gradients - There should be no significant effect on the existing salinity gradients.

5. Actions that will be taken to minimize impacts- None are required: however, the borrow area would be excavated in a manner to approximate natural ridge slopes to ensure normal water exchange and circulation. Utilization of sand from a clean, high energy environment and its excavation with a hydraulic dredge would also minimize water chemistry impacts.

C. Suspended Particulate/Turbidity Determinations

1. Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Disposal Site and Borrow Site - There would be a short-term elevation of suspended particulate concentrations during construction phases in the immediate vicinity of the dredging and the discharge. Elevated levels of particulate concentrations at the discharge locations may also result from "washout" after beachfill is placed.

2. Effects (dredge and duration) on Chemical and Physical Properties of the Water Column -

   a. Light penetration - Short-term, limited reductions would be expected at the borrow and disposal sites from dredge activity and berm washout, respectively.

   b. Dissolved oxygen - There is a potential for a decrease in dissolved oxygen levels but the anticipated low levels of organics in the borrow material should not generate a high, if any, oxygen demand.

   c. Toxic metals and organics - Because the borrow material originates from a clean, high energy environment, and because it is essentially all medium to fine sand, no toxic metals or organics are anticipated.

   d. Pathogens - Pathogenic organisms are not known or expected to be a problem in the borrow or disposal area.

- e. Aesthetics - Construction activities and the initial construction template associated with the fill site would result in a minor, short-term degradation of aesthetics.

3. Effects on Biota

   a. Primary production, photosynthesis - Minor, short-term effects related to turbidity.

   b. Suspension/filter feeders - Minor, short-term effects related to suspended particulates outside the immediate deposition zone. Sessile organisms would be subject to burial if within the deposition area.

   c. Sight feeders - Minor, short-term effects related to turbidity.

4. Actions taken to minimize impacts include the selection of clean sand with a small fine grain component and a low organic content. Standard construction practices would also be employed to minimize turbidity and erosion.

D. <u>Contaminant Determinations</u>

The discharge material is not expected to introduce, relocate, or increase contaminant levels at either the borrow or placement sites. This is assumed based on the characteristics of the sediment, the proximity of the borrow site to sources of contamination, the area's hydrodynamic regime, and existing water quality.

E. <u>Aquatic Ecosystem and Organism Determinations</u>

1. Effects on Plankton - The effects on plankton should be minor and mostly related to light level reduction due to turbidity. Significant dissolved oxygen level reductions are not anticipated.

2. Effects on Benthos - Although there is a major disruption of the benthic community in the borrow area when the fill material is excavated, the 404(b)(1) analysis focuses on the disposal area effects. Here the disruption is as significant as the entire community is subject to burial or displacement; however, the actual biomass of organisms impacted is far less due to the harsher environmental conditions present on the beach and in the surf zone. The loss is somewhat offset by the expected rapid opportunistic

recolonization from adjacent areas that would occur following cessation of construction activities. Recolonization is expected to occur in the disposal (beachfill placement) area through horizontal and in some cases vertical migrations of benthos.

3. Effects on Nekton - Only a temporary displacement is expected as the nekton would probably avoid the active work area.

4. Effects on Aquatic Food Web - Only a minor, short-term impact on the food web is anticipated. This impact would extend beyond the construction period until the recolonization of buried areas had occurred.

5. Effect on Special Aquatic Sites - No special aquatic sites are present within the project area.

6. Threatened and Endangered Species - The piping plover (Charadrius melodus), a Federal and State threatened species, could potentially be impacted by the proposed project. This bird nests on the beach, however, no nesting sites have been observed within the project area. Several species of threatened and endangered sea turtles may be migrating through the sand borrow area depending on the time of year. Sea turtles have been known to become entrained and subsequently destroyed by suction hopper dredges. Use of a hopper dredge during a time of high likely presence in the area could potentially entrain and destroy a sea turtle(s).

7. Other Wildlife - The proposed plan would not affect other wildlife.

8. Actions to minimize impacts - Impacts to benthic resources can be minimized at the borrow area by dredging in a manner as to avoid the creation of deep pits and alternating locations of periodic dredging. Impacts to Federal and State threatened piping plover can be avoided or minimized by establishing a buffer zone around a piping plover nest(s) and limiting construction outside of the nesting season. Depending on the timing of the dredging and the type of dredge to be used, it may be necessary to implement mitigative measures to avoid adversely impacting threatened or endangered sea turtles. If a hopper dredge (with suction head) is used, measures to avoid or minimize impacts to these species may include but not be limited to utilizing NMFS approved turtle monitors, utilizing specially modified hopper dredges, and use of trawlers that can intercept and transport turtles away from the dredging impact area. It may not be necessary to

implement these measures if dredging is conducted within the winter months when turtle activity is lowest in this area. These measures would be implemented based on the findings of the forthcoming Biological Opinion to be issued by NMFS.

F. Proposed Disposal Site Determinations

1. Mixing Zone Determination

a. Depth of water - 0 to-20 feet mean low water
b. Current velocity - Generally under 3 feet per second
c. Degree of turbulence - Moderate to high
d. Stratification - None
e. Discharge vessel speed and direction - Not applicable
f. Rate of discharge - Typically this is estimated to be 780 cubic yards per hour

g. Dredged material characteristics - medium-fine sand
h. Number of discharge actions per unit time - Continuous over the construction period

2. Determination of compliance with applicable water quality standards - Prior to construction, a Section 401 Water Quality Certificate and consistency concurrence with the State's Coastal Zone Management Program will be obtained from the State of Delaware.

3. Potential Effects on Human Use Characteristics -

a. Municipal and private water supply - No effect
b. Recreational and commercial fisheries - Short-term effect during construction; there would be a minor loss of surfclam stocks within the borrow area from dredging.
c. Water related recreation - Short-term effect during construction
d. Aesthetics - Short-term effect during construction
e. Parks, national and historic monuments, national seashores, wilderness areas, etc. - No effect

G. Determination of Cumulative Effects on the Aquatic Ecosystem- None anticipated.

H. Determination of Secondary Effects on the Aquatic Ecosystem Any secondary effects would be minor and of short duration.

III. **<u>FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE</u>**

A. No significant adaptation of the Section 404(b)(1) Guidelines were made relative to this evaluation.

B. The alternative measures considered for accomplishing the project objectives are detailed in Section 3 of the document of which this 404(b)(1) analysis is a part.

C. A water quality certificate will be obtained from the Delaware Department of Natural Resources and Environmental Control.

D. The proposed beach nourishment will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

E. The proposed beach nourishment will comply with the Endangered Species Act of 1973. Informal coordination procedures have been completed.

F. The proposed beach nourishment will not violate the protective measures for any Marine Sanctuaries designated by the Marine Protection, Research, and Sanctuaries Act of 1972.

G. The proposed beach nourishment will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. Significant adverse effects on lifestages of aquatic life and other wildlife dependent on aquatic ecosystems; aquatic ecosystem diversity, productivity, and stability; and recreational, aesthetic, and economic values will not occur.

H. Appropriate steps to minimize potential adverse impacts of the discharge on aquatic systems include selection of borrow material that is low in silt content, has little organic material, and is uncontaminated.

I. On the basis of the guidelines, the proposed disposal site for the dredged material is specified as complying with the requirements of these guidelines, with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects on the aquatic ecosystem.

9.0 CLEAN AIR ACT STATEMENT OF CONFORMITY

CLEAN AIR ACT
STATEMENT OF CONFORMITY
REHOBOTH BEACH/DEWEY BEACH STORM DAMAGE REDUCTION PROJECT
SUSSEX COUNTY, DELAWARE

Based on the conformity analysis in the subject report I have determined that the proposed action conforms to the applicable State Implementation Plan (SIP), the Environmental Protection Agency had no adverse comments under their Clean Air Act authority. No comments from the air quality management district were received during coordination of the draft feasibility report. The proposed project would comply with Section 176 (c)(1) of the Clean Air Act Amendments of 1990.

6/18/96
Date

Robert P. Magnifico
Robert P. Magnifico
Lieutenant Colonel, Corps of Engineers
District Engineer

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11.0 INDEX

CONCLUSIONS

360. As a requirement in completing the feasibility study, a public notice shall be issued to inform all interested parties of the plan discussed herein. Because the design of the recommended plan is not technically complex and is essentially complete, a typical Design Memorandum would not be required before the initiation of construction. The only technical work remaining consists of additional geotechnical sampling/testing of the borrow site to finalize the site dimensions of the sand source for initial beachfill, and final environmental coordination and documentation which can be accomplished concurrent with preparation of plans and specifications for construction. In the event this study leads to Federal construction, the costs for these activities shall be reimbursed by the non-Federal sponsor as a project cost shared item.

361. The selected plan for this interim feasibility report, the first of three interim feasibility reports executed under one FCSA (see Paragraphs 1. and 7.), is a storm damage reduction plan (detailed in Paragraphs 313. through 317.) that generally extends from 1000 feet north of the Rehoboth Beach town border to 1000 feet south of the Dewey Beach town border, for a total length of 13,500 feet, and consists of:

- For Rehoboth Beach, a berm extending seaward 125 ft from the design line at an elevation of +8 ft NGVD. For Dewey Beach, a berm extending seaward 150 ft from the design line at an elevation of +8 ft NGVD. Both berm plans have a foreshore slope of 1V:15H to mean low water (MLW). From MLW seaward the slope parallels the bottom out to the depth of closure. The beachfill extends from the northern end of Rehoboth Beach through the Silver Lake area to the southern border of Dewey Beach, and tapers into the existing shoreline in the north end at Deauville and in the southern end at North Indian Beach, for a total length of 13,500 l.f.

- On top of both berm plans in both communities lies a dune with a top elevation of +14 ft NGVD and a top width of 25 ft. The landward and seaward slope of the dune face is 1V:5H. A total sand fill quantity of 1,437,000 cubic yards is needed for the initial fill placement in Rehoboth Beach and Dewey Beach.

- 17.5 acres of planted dune grass and 16,400 l.f. of sand fence for entrapment of sand on the dune and delineating walkovers and vehicle access ramps.

- 39 dune walkovers and 2 vehicle access ramps over the dune. (Schematics of these structures are shown in Appendix A, Section 6.

- Renourishment of approximately 360,000 cubic yards of sand fill from the offshore borrow area every 3 years for the 50 year project life.

- Beachfill for the proposed project is available from an offshore borrow area containing approximately 5 million cubic yards of suitable beachfill material. The borrow area is located approximately 3 miles offshore of the Rehoboth Beach/ Dewey Beach area. Details of the borrow site and the borrow material are provided in Appendix A, Section 4.

- To properly assess the functioning of the proposed plan, monitoring of the placed beachfill, borrow area, shoreline, wave and littoral environment is included with the plan. Environmental monitoring is being addressed through coordination with other interested agencies, and will be finalized in the Final Environmental Impact Statement for the project. The proposed Coastal Monitoring Plan is presented in Appendix A, Section 5.

362. If this project were to go to construction, the Federal Government would contribute 65% of the first cost of the selected plan, which is currently estimated to be $9,114,000. Periodic nourishment of the selected plan would be similarly cost shared.

363. The plan described above is subject to modification at the discretion of the Commander, HQUSACE.

RECOMMENDATION

364. In making the following recommendation. I have given consideration to all significant aspects in the overall public interest, including environmental, social effects, economic effects, engineering feasibility and compatibility of the project with the policies, desires and capabilities of the State of Delaware and other non-Federal interests. A plan has been identified that is technically sound, economically justified, and socially and environmentally acceptable; however, the current Administration's budgetary policy precludes further Federal participation in the design and construction of hurricane and storm damage reduction projects.

365. The recommendations contained herein reflect the information available at the time and current Departmental policies governing formulation of individual projects. These recommendations may be modified before they are transmitted to the Congress. However, prior to transmittal to the Congress, the Sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Robert P. Magnifico

Robert P. Magnifico
Lieutenant Colonel, Corps of Engineers
District Engineer

APPENDIX D

PERTINENT CORRESPONDENCE

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF FISH AND WILDLIFE
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19902

OFFICE OF THE
DIRECTOR

March 16, 1993

Mr. Steve Allen
U.S. Army Corps of Engineers
John Wanamaker Building
Environmental Resource
100 Penn Square East
Philadelphia, PA 19107-3390

Dear Steve:

Enclosed is the data summary from our 11 November 1992 Surf Clam Survey of Delaware's coastal waters. A total of 31 ten - minute tows were taken by hydraulic dredge from the fishing vessel "Betty C", a commercial clammer out of Ocean City, Maryland. The stations encompassed the entire Delaware coast from Fenwick Island to Brown Shoal. A total of 8 stations were on Hen and Chickens Shoal. The dredge had approximately 65 minutes of bottom time on the shoal. No commercial size Spisula were caught on the shoal or elsewhere during this survey.

Surf clams were harvested extensively from state controlled waters, within 3 miles, during the early 1970's. At that time Hen and Chickens Shoal was an important harvesting area. The dominant 1976 year-class which supports New Jersey's inshore fishery, did not occur in Delaware waters. Two subsequent surveys during the 1980's and this 1992 survey have failed to find any commercially exploitable resource. The Division of Fish and Wildlife has no concerns at the present time about the creation of a beach nourishment borrow area on the shoal, since there is no conflict at this time with shellfish resources. Please bear in mind, however, that this area is prime habitat for surf clams and has supported extensive harvesting in the past. In establishing a borrow site for the next 50 years, the potential for future conflicts with commercial shellfish harvesting does exist.
We do not feel that further survey work need be done at this time. Please keep me posted on your benthic survey work on this site.

If I may be of further assistance, please contact me at your convenience.

Sincerely,

Jeff C. Tinsman

Jeff C. Tinsman
Fisheries Biologist

F/V Retu C   Surf Clam Survey 1992

11-17-92   Buddy [illegible] / Stew [illegible]

	START	STOP	TOW TIME	CLAMS
1	27081.5 42410.9	27079.8 42415.3	10 MIN	0
2	[illegible] 42415.6	27074.7 [illegible]	10 MIN	0
3	27096.9 42419.2	[illegible] [illegible]	10 MIN	0
4	[illegible] [illegible]	[illegible] [illegible]	12 MIN	0
5	[illegible] 42439.5	[illegible] 42443.5	10 MIN	0
6	27099.8 42461.7	27100.5 42462.8	2 MIN	0
7	27101.7 42467.7	HAUL BACK DID NOT MOVE		
8	27102.7 42471.7	27103.2 42474.6	5 MIN	0
9	27102.6 42475.2	27100.9 42476.9	6 MIN	0
10	27101.3 42479.9	27103.0 42484.9	10 MIN	0
11	[illegible] [illegible]	[illegible] [illegible]	12 MIN	0
12	[illegible] 42492.2	27109.4 [illegible]	4 MIN	0
13	27111.1 42499.7	HAUL BACK STUCK		
14	27116.6 42517.0	HAUL BACK CLAY		

15	27115.4 42532.4	27114.2 42543.9	10 min	0
16	27114.6 42538.8	27116.8 42543.9	9.5 MIN	0
17	27120.1 42544.2	27121.1 42547.5	5 MIN	0
18	[illegible]	HAUL BACK HARD BOT		
19	27124.6 42570.0	HAUL BACK MUD		
20	27127.7 42589.1	HAUL BACK HARD BOT		
21	27127.7 42594.2	27129.2 42601.4	10 MIN	0
22	27133.5 42599.7	27136.3 42606.6	10 MIN	0
23	27139.1 42609.6	HIT HARD 27159.0 BENT DREDGE 42612.2 (ROCK?)	5 MIN	0
24	27142.1 42617.1	27145.0 42624.2	10 MIN	0
25	27131.1 42602.1	27132.2 42608.3	10 MIN	0
27	27136.1 42615.9	27139.5 42620.6	10 MIN	0
28	27170.1 42669.8	27170.6 42671.0	3 MIN	0
29	27184.1 42675.0	27170.9 42685.6	10 MIN	0
30	27181.1 426720.6	27181.7 42724.6	7.5 MIN	0
31	27179.1 42752.9	27176.5 42757.8	15 MIN	0

STNS 20-27

SHOAL

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL
ROOM 2115 FEDERAL BUILDING
300 South New Street
Dover, Delaware 19901-6790
302-674-2331
FAX 302-674-5399

Dr. Lee G. Anderson
Chairman

William S. Wells
Vice Chairman

John C. Bryson, P.E.
Executive Director

28 July 1992

Mr. R. F. Sliwoski
District Engineer
Corps of Engineers
Wanamaker Building
100 Penn Square
Phila., PA 19107

Dear Mr. Sliwoski:

We received your 18 July notice of the initiation of the feasibility phase for the Delaware Coast from Cape Henlopen to Fenwick Island shoreline protection study. We have provided your office with our Fishery Management Plans for summer flounder, bluefish, surf clams and ocean quahogs, and Atlantic mackerel, *Loligo*, *Illex*, and butterfish. We are in the process of developing management measures for scup, black sea bass, and weakfish. Obviously, we are concerned with any potential habitat degradation involving the above mentioned species.

Please keep us informed of your project's development. We will assist you in any way we can to minimally impact the habitat.

Sincerely yours,

David R Keifer /jm

John C. Bryson

cc: Dick Roe

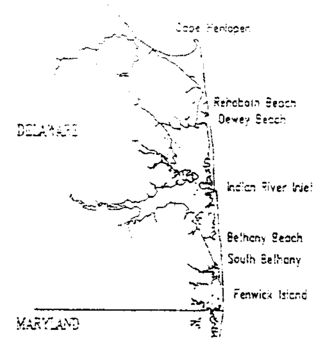
US Army Corps of Engineers
Philadelphia District

DELAWARE COAST

CAPE HENLOPEN TO FENWICK ISLAND, DELAWARE

A SHORELINE PROTECTION STUDY

May 1993 INFORMATION BULLETIN Number 1



Map of the Delaware ocean coast.

UPDATE

The Reconnaissance Phase (Recon Phase) of the Atlantic coast of Delaware from Cape Henlopen to Fenwick Island study was completed in September 1991. The Recon Phase, which was 100% federally funded, studied the entire coast to evaluate possible erosion and storm damage problems, and to determine whether further federal studies are warranted. The Recon Phase confirmed that beach erosion continues to be a problem along the coast of Delaware and suggested that future studies concentrate on the three areas of Rehoboth Beach/Dewey Beach, Bethany Beach/South Bethany Beach and Fenwick Island. High storm damage potential exists along the ocean coast of Delaware due to the historically narrow beaches, over most of the coastline, and the current level of development. This can best be illustrated by the heavy damage caused to coastal communities over the past 18 months by the three major storms (October 1991, January 1992 and December 1992) which have buffeted the Delaware coast.

It should also be mentioned that while some of the locations recommended for further study by the Recon Phase have relatively stable beach widths, these areas may still be vulnerable to significant damage from storm induced waves, surge, and erosion. With the expectation that development will continue, storm damage potential will likewise increase without an effective shore protection plan. Taking these problems into consideration it was concluded at the end of the Recon Phase that federal interest for shore protection exists for all three study sites. Federal interest is required for the study to continue into the Feasibility Phase.

Dewey Beach, note the narrow beach.

The Feasibility Phase was initiated on June 17, 1992, and is the second and final step in the two phase planning process for Corps of Engineers Civil Works projects. The purpose of this phase is to complete an in-depth analysis of each study site and evaluate alternative shore protection projects. Normally, the recommended plan must have the greatest net economic benefits and must be consistent with national environmental policy. This plan is known as the National Economic Development Plan, or the NED plan. A variation of the NED plan can be recommended if it is the plan preferred by the local sponsor. Local interests are encouraged to be actively involved during the Feasibility Phase because it is within this phase that a specific shore protection project begins to take shape.

The Feasibility Study Phase is cost shared 50/50 between the Federal Government and the local, non-Federal sponsor. The Delaware Department of Natural Resources and Environmental Control (DNREC) has agreed to be the non-Federal sponsor of the Delaware Coast- Cape Henlopen to Fenwick Island Feasibility Study.

The Feasibility Study for the ocean coast of Delaware is composed of three interim studies which are staggered in time. Each of the interim studies will culminate in an Interim Feasibility Report for each of the following three areas: Dewey Beach/Rehoboth Beach, Bethany Beach/South Bethany Beach, and Fenwick Island. This study plan was developed to address the highest priority areas first while ensuring that the ability of the non-Federal to cost share the study is not overburdened.

The first interim study, Rehoboth Beach/Dewey Beach, was initiated on June 17, 1992 and has a duration of approximately four years. It includes a concentrated effort at the study site as well as a coastwide analysis to evaluate large scale coastal processes associated with the Delaware ocean coast. The two subsequent interim studies, Bethany Beach/South Bethany Beach and Fenwick Island, each have durations of approximately three years, and are scheduled to begin in 1995 and 1997 respectively.

DATA COLLECTION

Existing detailed data of the coastal processes and sand resources along Delaware's coastline is limited. Therefore, a coastwide data collection and analysis effort is included in the early stages of the first interim study (Rehoboth Beach/Dewey Beach).

The coastwide analysis includes efforts to characterize the wave climate (wave height and direction), perform beach, land and hydrographic surveys, assess the sediment budget, determine the historic shoreline response and locate suitable offshore sand deposits for beachfill material. Once the potential borrow source area has been identified it must be determined whether there are cultural artifacts and/or ecologically important species in the area before it can be used.

To ascertain the wave climate of the Delaware ocean coast a wave gauge system was placed approximately 1800 feet off the shoreline of Dewey Beach in October 1992 by the Coastal Engineering Research Center (CERC) of the Waterways Experiment Station (WES). The wave gauge will allow the Corps to determine the height, period and direction of waves (wave climate) along the coast of Rehoboth and Dewey Beach. Data from this effort as well as data collected from beach, land and hydrographic surveys will be used as input into numerical models which simulate various coastal processes such as erosion, storm surge and shoreline change.

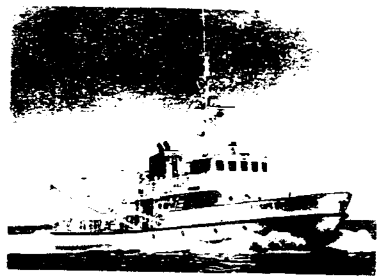
The wave gauge which was placed off Dewey Beach.

The wave gauge being placed off Dewey Beach by a Pennsylvania National Guard "Chinook" helicopter.

In September 1992 the Corps of Engineers obtained use of the University of Delaware R/V Cape Henlopen to conduct an offshore acoustic survey to identify the geologic features of the Delaware ocean coast. The acoustic data will be correlated with core samples which will be collected in June 1993. This effort will make it possible for the Corps to locate and identify sand deposits that are suitable for use as material for beach nourishment.

After potential borrow source material has been identified, the Corps will conduct magnetometer surveys to locate any shipwrecks or other cultural resources in the potential borrow area. In addition, biological sampling of the potential borrow area must be undertaken to determine whether it is inhabited by endangered or commercially valuable species of marine organisms. These efforts will help to ensure that any dredging efforts associated with a beachfill project will not disturb valuable artifacts off the Delaware coast or disturb any endangered or commercially valuable species of marine organisms. Only after passing these tests can an area be designated as a valid potential borrow source.

Another task the Corps is currently undertaking is the collection of aerial photographs of the entire ocean coast of Delaware. The photographs, along with detailed vertical and horizontal survey data, will be used to develop



The University of Delaware R/V Cape Henlopen was used to perform acoustic surveys off the Delaware ocean coast.

base maps and digital orthophotographs which will in turn be used as input to a Geographic Information System (GIS) which the Philadelphia District is currently developing. The use of GIS will allow the Corps to more effectively monitor erosion rates, storm damage, economic development and to identify areas prone to flooding during storms.

SHORE PROTECTION ALTERNATIVES

Coastal protection alternatives can be classified into two groups: non-structural and structural.

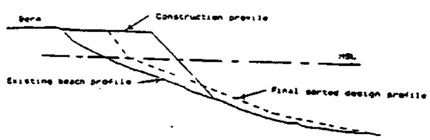
Non-structural protection methods consist of those which regulate the use of land and buildings to reduce or eliminate damages to property. For example, such measures can include zoning legislation and building codes which may establish building setback lines and elevation requirements. Retreat is also a non-structural method but this must be weighed against the current level of development, the economic base of shore regions and the persistent desire of living near the ocean.

Structural shore protection methods are those which block or inhibit the erosive coastal processes or which restore or nourish beaches to compensate for erosion.

Shore parallel structures include bulkheads, revetments, and seawalls. Generally these types of structures are used to retain sand and/or reduce direct wave attack to the backshore zone. Breakwaters are also parallel but are located offshore to dissipate incoming wave energy.

An additional shore parallel structure is beach/dune nourishment, the placement of sand on a beach to provide a larger dune/berm system. This option is usually less expensive and more environmentally favorable than other structural methods and is becoming the more commonly recommended solution to coastal erosion/protection problems. However, the placement of sand on a beach as fill is an often misunderstood solution.

The fill is used to raise the elevation of the beach dune and berm profiles, and widen the beach to extend the "buffer" between land and sea. Below is a diagram showing a beach fill template including the natural, construction, and design profiles.



An example of a beach fill template showing the construction profile and the final sorted design profile.

The constructed berm is not built to exactly fit the design template since the material is redistributed by natural wave action to conform to the design profile thereby carrying the sand to the offshore zone. This is why many beachfill projects appear to erode soon after their construction. Because erosion is an ongoing process, a long-term beach renourishment program is required to maintain the desired level of shore protection after the initial beachfill.

Shore perpendicular structures such as groins and jetties, have the ability to hold sand while allowing sand transport along the shore when properly designed. In general, these structures are expensive to construct, however, when properly designed they may reduce the need for future renourishment.

COMMENTS

We appreciate public and private involvement in these ongoing studies. It is helpful to us, and will become even more important as we move into the planning and development of specific coastal projects.

If you are concerned with coastal problems in the study areas, please address your comments to the Philadelphia District at our address on the attached Comment Form.

COMMENT FORM

If you have any comments on the Delaware Coast- Cape Henlopen to Fenwick Island Feasibility Study or corrections, additions or deletions for our mailing list, please let us know by cutting out the following coupon and mailing it to:

Department of the Army
U.S. Army Engineer District, Philadelphia
Attn: CENAP-PL-PC
Wanamaker Building
100 Penn Square East
Philadelphia, Pennsylvania 19107

______ Yes. Please correct or add me to your Delaware Coast- Cape Henlopen to Fenwick Island Feasibility Study mailing list.

______ No. Please delete my name to the mailing list.

NAME:__________________PHONE:(Optional)_______________

ADDRESS:____

____

COMMENTS:____

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
WANAMAKER BUILDING, 100 PENN SQUARE EAST
PHILADELPHIA, PENNSYLVANIA 19107-3390

REPLY TO
ATTENTION OF

30 JUN 1992

Planning Division

NOTICE OF STUDY INITIATION

This notice is to announce the initiation of the feasibility phase for the Delaware Coast from Cape Henlopen to Fenwick Island shoreline protection study. The Corps of Engineers is conducting this study in response to a resolution adopted by the U. S. Senate Committee on Environment and Public Works on June 23, 1988. This study is being sponsored by the Delaware Department of Natural Resources and Environmental Control (DNREC).

The purpose of the study is to investigate shore protection problems along the entire Atlantic coast of Delaware with a view to determining the advisability of providing improvements in the interest of beach erosion control, hurricane protection, and related purposes. Included in this study will be the development of a physical and environmental database on coastal area changes and processes, including appropriate monitoring during development of the database, as the basis for actions to prevent the harmful effects of shoreline erosion and storm damage.

The first phase of the study, the reconnaissance phase, was completed in 1991 at 100% Federal cost. The reconnaissance phase established that there is Federal interest in establishing shoreline protection measures along the Atlantic coast of Delaware. The second phase of the study, the feasibility phase, began in June 1992 and will be cost shared 50%-50% between the State of Delaware (DNREC) and the Federal government. The feasibility study will primarily investigate shore protection problems along the Atlantic coast of Delaware and develop detailed solutions as well as an economic assessment of the viability of each chosen solution. Additionally, the feasibility study will include an assessment on the level of interest and support of non-Federal parties in the identified potential solutions, and establish the scope and schedule for the construction of future shore protection measures.

Any pertinent information that Federal, State or local agencies and the private sector can provide will be used to the greatest extent possible. We welcome any assistance and suggestions pertaining to the conduct of this study. All comments should be directed to the above address, ATTN: CENAP-PL-PC.

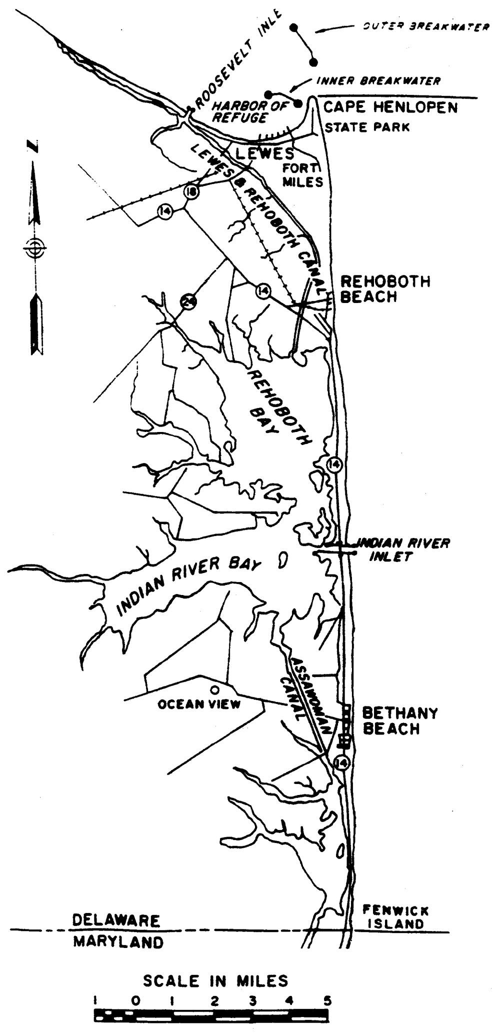
Sincerely,

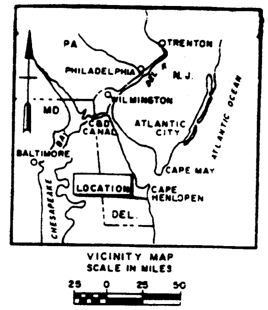
Edwin H. Clark, II

Edwin H. Clark, II, Secretary
Delaware Department
Natural Resources and
Environmental Control

R. F. Sliwoski

R. F. Sliwoski
Lieutenant Colonel, Corps of Engineers
District Engineer





DELAWARE COAST - CAPE HENLOPEN TO FENWICK ISLAND, DE STUDY

U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

OFFICE OF THE SECRETARY

TELEPHONE (302) 739-4403
FAX (302) 739-6242

October 8, 1991

Lt. Colonel Kenneth H. Clow
District Engineer
U.S. Army Corps of Engineers
Custom House
2nd & Chestnut Streets
Philadelphia, PA 19106

Dear Colonel Clow:

This concerns the Corps of Engineers Reconnaissance Study for the Delaware Atlantic Coast from Cape Henlopen to Fenwick Island. The Delaware Department of Natural Resources and Environmental Control (DNREC) and the U.S. Army Corps of Engineers have concluded negotiations on a Draft Feasibility Study Cost-Sharing Agreement (FCSA) for a study of the Delaware Coast from Cape Henlopen to Fenwick Island. We have reviewed and approved the model FCSA supplied by the Philadelphia District, and we intend to provide the Non-Federal cash contribution as stipulated in Article II. Further, at such time as the Reconnaissance Report is certified we are willing to execute the document.

We understand and accept that the Feasibility Study may not necessarily lead to construction of a project to reduce shoreline erosion and storm damage potential, although evaluations to date, as presented in the Reconnaissance Report, indicate that a project(s) for shoreline protection appears to be justified and feasible.

Sincerely,

Edwin H. Clark, II

Edwin H. Clark, II
Secretary

CENAP-PL-E

ALLEN
jc/6555
18 Aug 93

PASQUALE

KEON

WARE

TUNNELL

CALLEGARI

Environmental Resources Branch

AUG 1 9 1993

Mr. John P. Wolflin, Supervisor
U.S. Fish and Wildlife Service
Chesapeake Field Office
1825 Virginia Street
Annapolis, Maryland 21401

ATTN: George Ruddy

Dear Mr. Wolflin:

Enclosed for your review and comment is the "Draft Benthic Animal-Sediment Assessment of a Potential Beachfill Borrow Source For the Rehoboth/Dewey Beach, Delaware Interim Feasibility Study". The benthic study area is located within Hen and Chickens Shoal, and has sample stations located throughout the proposed 550-acre sand borrow site plus an additional 110 acres north and south of the site for use as control areas. The objectives and sampling methodology of the benthic study were coordinated with Mr. George Ruddy of your office prior to undertaking this study. The information generated from this report will be subsequently used to supplement existing data for the Fiscal Year 1993 Planning Aid Report for this project.

Please review this report and provide any written comments within 21 days of the date of this letter. Questions on this study can be directed to Steve Allen of the Environmental Resources Branch at (215) 656-6559. Thank you.

Sincerely,

Robert L. Callegari
Chief, Planning Division

MFR: This letter is intended to coordinate technical review with interested resource agencies on the benthic sampling for the proposed sand borrow site for the Rehoboth/Dewey Beach Study.

CENAP-PL-E
6559/am
SEP 2 6 1994
26 SEPTEMBER 1994
ALLEN
PASQUALE
KEON
TUNNELL
BURNES
CALLEGARI

Environmental Resources Branch

Mr. John P. Wolflin
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Attn: Mr. George Ruddy

Dear Mr. Wolflin:

This is in regards to the Delaware Atlantic Coast - Rehoboth Beach and Dewey Beach Interim Feasibility Study, which is addressing the potential for Federal involvement in shore protection along this section of coastline. We are seeking consultation with your office regarding a small portion of beach (0.25 miles long) adjacent to Silver Lake between Rehoboth Beach and Dewey Beach that is included in the Coastal Barrier Resources System (CBRS). The Coastal Barrier Resources Act (CBRA) prohibits expenditure of Federal funds which might encourage development in the Coastal Barrier Resources System. This may be problematic since the 0.25 mile long CBRS area falls between two communities which have been identified as having the potential for major storm damage. We are currently evaluating alternative shore protection plans for Rehoboth Beach and Dewey Beach, which would most likely involve beach nourishment. Therefore, it may be technically inappropriate from an engineering perspective to preclude this area from potential construction. Recent site visits by Service and Corps staff have confirmed that this CBRS area is already experiencing residential development on the barrier beach adjacent to Silver Lake, which is expected to continue, with or without any future Federal involvement in shore protection.

We are not aware of any formal procedure for consulting with the Service for the CBRA, however, we are seeking your assistance in developing a plan that would enable us to comply with the CBRA and provide the necessary storm damage reduction for both Rehoboth Beach and Dewey Beach. Questions on this matter can be directed to Steve Allen of the Environmental Resources Branch at (215) 656-6559. Thank-you for your cooperation.

Sincerely,

Robert L. Callegari
Chief, Planning Division

Enclosure

Copy Furnished:
Bob Henry, DNREC

MFR: CENAD has identified this as an issue in the P4 review and suggest that we consult with USFWS on CBRA. This letter was coordinated with Project Development Branch.

CENAP-PL-E

ALLEN
jc/6555
18 Aug 93

AUG 1 9 1993

PASQUALE

KEON

WARE

TUNNELL

CALLEGARI

Environmental Resources Branch

Mr. Jeff Tinsman
Delaware Department of Natural
Resources and Environmental Control
Division of Fish and Wildlife
89 Kings Highway
P.O. Box 1401
Dover, Delaware 19903

Dear Mr. Tinsman:

Enclosed for your review and comment is the "Draft Benthic Animal-Sediment Assessment of a Potential Beachfill Borrow Source For the Rehoboth/Dewey Beach, Delaware Interim Feasibility Study". The benthic study area is located within Hen and Chickens Shoal, and has sample stations located throughout the proposed 550-acre sand borrow site plus an additional 110 acres north and south of the site for use as control areas. The objectives and sampling methodology of the benthic study were coordinated with your office prior to undertaking this study.

Please review this report and provide any written comments within 21 days of the date of this letter. Questions on this study can be directed to Steve Allen of the Environmental Resources Branch at (215) 656-6559. Thank you.

Sincerely,

Robert L. Callegari
Chief, Planning Division

MFR: This letter is intended to coordinate technical review with interested resource agencies on the benthic sampling for the proposed sand borrow site for the Rehoboth/Dewey Beach Study.

CENAP-PL-E

ALLEN
jo/6555
18 Aug 93

PASQUALE

Environmental Resources Branch AUG 1 9 1993

KEON

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TUNNELL

CALLEGARI

Mr. John R. Maxted
Delaware Department of Natural
Resources and Environmental Control
Division of Water Resources
P.O. Box 1401
Dover, Delaware 19903

Dear Mr. Maxted:

Enclosed for your review and comment is the "Draft Benthic Animal-Sediment Assessment of a Potential Beachfill Borrow Source for the Rehoboth/Dewey Beach, Delaware Interim Feasibility Study". The benthic study area is located within Hen and Chickens Shoal and has sample stations located throughout the proposed 550-acre sand borrow site plus an additional 110 acres north and south of the site for use as control areas. The objectives and sampling methodology of the benthic study were coordinated with your office prior to undertaking this study.

Please review this report and provide any written comments within 21 days of the date of this letter. Questions on this study can be directed to Steve Allen of the Environmental Resources Branch at (215) 656-6559. Thank you.

Sincerely,

Robert L. Callegari
Chief, Planning Division

MFR: This letter is intended to coordinate technical review with interested resource agencies on the benthic sampling for the proposed sand borrow site for the Rehoboth/Dewey Beach Study.

DELAWARE HEALTH AND SOCIAL SERVICES
DIVISION OF PUBLIC HEALTH

January 26, 1994

Steve Allen
U.S. Army Corps of Engineers
Wannamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390

Attn: Environmental Resources Branch

Dear Mr. Allen,

Enclosed, is the information that you requested. This includes yearly statistical analyses and raw data. The Division of Public Health has not issued a swimmer advisory for Rehoboth, Dewey Beach, or any ocean beach for that matter, for over two years. We appreciate being contacted regarding the proposed dredging/beach replenishment.

If you have any questions or concerns, please contact me at (302) 739-5410.

Sincerely,

Jack Pingree
Program Manager
Office of Shellfish
& Recreational Water

JP/tr
Enclosure

FEB 14 1994

SWANDA
mls/6556
14 Feb 94
PASQUALI
BURNES
CALLEGARI

Environmental Resources Branch

Ms. Faye L. Stocum
Environmental Review Coordinator
Bureau of Archaeology and Historic Preservation
Division of Historical and Cultural Affairs
#15 The Green, P.O. Box 1401
Dover, Delaware 19901

Dear Ms. Stocum:

The U.S. Army Corps of Engineers, Philadelphia District has recently conducted an underwater remote sensing survey within two potential borrow areas off the Atlantic Coast near Dewey Beach and Bethany Beach, Delaware. A draft report of this investigation entitled Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape Henlopen to Fenwick Island (Dolan Research, Inc., February 1994) is enclosed for your review. This survey identified three targets suggestive of submerged cultural resources and were designated as high probability targets. Avoidance of these targets during sand dredging activities is recommended.

Your review and comments of this report would be most helpful if received within 30 days. Please do not hesitate to contact Michael Swanda, Environmental Resources Branch at (215) 656-6556 if you have any questions or need further information.

Sincerely,

Robert L. Callegari
Chief, Planning Division

Enclosures

CF:
CENAP-PL-PC, Hanrahan

MFR: This letter requests Section 106 comments from the Delaware SHPO..

Mike Swanda
CENAP-PL-E

CENAP-PL-E

NOV 29 1994

SWANDA
mls/6556
28 Nov 94

PASQUALE

BURNES

CALLEGARI

Environmental Resources Branch

Ms. Faye L. Stocum
Environmental Review Coordinator
Bureau of Archaeology and Historic Preservation
Division of Historical and Cultural Affairs
#15 The Green, P.O. Box 1401
Dover, Delaware 19901

Dear Ms. Stocum:

The U.S. Army Corps of Engineers, Philadelphia District completed an underwater remote sensing survey within two potential borrow areas off the Atlantic Coast near Dewey Beach and Bethany Beach, Delaware in 1990 for the Delaware Coast from Cape Henlopen to Fenwick Island Feasibility Study. A draft report of this investigation, entitled Submerged Cultural Resources Investigation, Delaware Atlantic Coast From Cape henlopen to Fenwick Island (Dolan Research, Inc., February, 1994), was submitted to your office for review and comment on February 14, 1994. The District must proceed with final report production in order to process final payment for this contract.

The Philadelphia District plans to follow the draft report recommendations and avoid the three targets exhibiting shipwreck characteristics during sand borrowing activities by delineating at least a 200 foot buffer around each target. The District does not anticipate any adverse impacts on significant cultural resources resulting from the placement of sand as beachfill within the project area. The project shoreline is located in a highly unstable and shifting coastal environment where the presence of intact and undisturbed archaeological material is considered minimal.

The District will incorporate any draft report comments you may have into the final report if received within 30 days from the date of this letter. Please do not hesitate to contact Michael Swanda, Environmental Resources Branch at (215) 656-6556 if you have any questions or need further information.

Sincerely,

Robert L. Callegari
Chief, Planning Division

CF:

CENAP-PL-PC, Hanrahan
MFR: This letter requests DESHPO Section 106 comments.

Mike Swanda
CENAP-PL-E

STATE OF DELAWARE
DEPARTMENT OF STATE
DIVISION OF HISTORICAL AND CULTURAL AFFAIRS
HISTORIC PRESERVATION OFFICE
15 THE GREEN
DOVER • DE • 19901-3611

TELEPHONE: (302) 739-5685 FAX: (302) 739-5660

December 1, 1994

Mr. Michael Swanda
Archaeologist
Environmental Resources Branch
Philadelphia District, Corps of Engineers
100 Penn Square East
Philadelphia, PA 19107-3390

Dear Mike:

This letter is pursuant to my review of the draft report entitled **Submerged Cultural Resources Investigation Delaware Atlantic Coast from Cape Henlopen to Fenwick Island,** prepared by Dolan Research Inc. Based on this review, it is our opinion that the consultant has provided your agency with important cultural resource information upon which to make pertinent management decisions for this project. The consultant has identified three (3)remote sensing targets which should be given additional survey consideration. We concur with the consultant that further survey work is required, if continued avoidance of these targets cannot be achieved.

Finally, pursuant to our review of this report against the Secretary of the Interior's **Standards and Guidelines for Archeology and Historic Preservation: Preservation Planning and Identification** (48 FR 44716 - 44723), there are some concerns. Some adjustments to the text are needed to bring this report into conformance with these **Standards and Guidelines**. Comments have been attached which should be reviewed by the consultant.

If you have any questions, or require any additional assistance, please do not hesitate to contact me at your convenience. Thank you.

Sincerely,

Faye L. Stocum

Faye L. Stocum
Archaeologist

Enclosure

cc: J. Lee Cox

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401

December 15, 1994

Lt. Colonel Robert P. Magnifico
District Engineer
U.S. Army Corps of Engineers
100 Penn Square East
Philadelphia, PA 19107-3390

Attn: Steve Allen

Re: Rehoboth/Dewey Beach [illegible]
Feasibility Study

Dear Colonel Magnifico:

This responds to Mr. Callegari's letter dated September 26, 1994, initiating consultation under the Coastal Barrier Resources Act for the subject study. A small section of beach (approximately 1,000 feet long) adjacent to Silver Lake between Rehoboth Beach and Dewey Beach is included within the Coastal Barrier Resources System (CBRS). Mr. Callegari's letter points out that since both Rehoboth Beach and Dewey Beach have been identified as vulnerable to storm damage, it may not be technically feasible to exclude from the project the short CBRS unit that lies between them.

The Act specifically allows Federal expenditures for "nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore natural stabilization systems provided they are consistent with the purposes of the Act". The Act's purpose is "to minimize the loss of human life, wasteful expenditure of Federal revenues, and the damage to fish, wildlife and other natural resources associated with the coastal barriers...by restricting future Federal expenditures...which have the effect of encouraging development of coastal barriers".

The CBRS unit adjacent to Silver Lake is composed of two land parcels which have both come under heavy pressure for residential development during the past year. A legal dispute over the right-of-way for vehicle access to the southern parcel within the town of Dewey Beach was recently settled. As a result, this past summer an asphalt road was constructed across the length of the barrier from Rehoboth Beach to Dewey Beach. Water and sewer lines have also been installed. The Dewey Beach parcel has been subdivided into seven building lots which are being marketed for sale under the name, Silver Lake Dunes. The real estate firm handling four of these lots revealed that the current per lot prices range from $375,000 to $595,000. A rather large custom built house has just been constructed on one lot, along with an elevated boardwalk across the dune to the beach. The parcel on the north end of the barrier just received preliminary approval in November for subdivision into seven new residential lots.

Because the development pressure is intense, it may proceed with or without a Corps project. However, the high vulnerability of this area to storm damage may yet prove to be a deterrent to complete development. Therefore a Corps storm protection project could increase the rate or extent of development by allaying the fears of prospective buyers.

In order for the project to be in compliance with the CBRA we recommend that the planning be conducted in accordance with the following guidelines.

1. Any construction within the CBRS unit should be the minimum necessary to ensure the functional integrity of the project in the adjacent areas of Rehoboth Beach and Dewey Beach.

2. The project benefit/cost analysis should not claim any benefits to existing or future residential development within the CBRS unit.

We would also like to take this opportunity to address the issue of potential ecological benefits from reinforcing the Silver Lake barrier. Without any human intervention ocean overwash into Silver Lake will become increasingly common. The resulting salinity increase in the Lake would alter the Lake's ecology, adversely affecting some species while benefitting others. We do not believe that the net effect of this change would be a significant adverse result for fish and wildlife resources. Therefore, we do not believe it is appropriate to ascribe biological benefits to a Federal project to reinforce the Silver Lake barrier.

We appreciate your inquiry on this matter. If there are any questions, please contact George Ruddy at (410) 573-4528.

Sincerely,

for John P. Wolflin
Supervisor
Chesapeake Bay Field Office

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF FISH AND WILDLIFE
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

OFFICE OF THE
DIRECTOR

21 February 1995

Steve Allen
Environmental Resources Branch
Philadelphia District
U.S. Corps of Engineers
Wannamaker Bldg.
100 Penn Sq. E.
Philadelphia, PA 19107-3390

SUBJECT: Heritage data request for Rehoboth Beach

Dear Mr. Allen:

A review of the Delaware Natural Heritage Program's database reveals that there are no documented records for any State Species of Special Concern or Federally listed species within the proposed project impact areas (xxxx). Several species of concern have been reported from immediately adjacent to your "adjacent areas for environmental consideration" (----). These include the common tern, *Sterna hirundo*, S1B, S3N (1-5 breeding sites statewide, 21-100 non-breeding sites statewide), the oystercatcher, *Haemotopus palliatus*, S2B (6-20 breeding sites statewide), and a bladderwort, *Utricularia subulata*, S2 (6-20 sites statewide). These two birds are known to nest on beaches and dunes (though it is not clear from our data if they were nesting at these locales), while the bladderwort is known from several interdunal swales south of the project area. We are unaware of any colonial nesting bird sites within the proposed project impact area or in the adjacent area of environmental consideration, though it is possible that in future years the less-developed areas (e.g. in the south end) may support colonial nesters. It is recommended that dunal areas south of the developed area of Rehoboth Beach be avoided.

We have no data on the offshore sites that will be the source of the sand, but we are concerned about potential impacts that may occur to the fauna of this area. Will the offshore sand be pumped ashore, or will it be dredged and loaded onto barges? Regardless of the method, what measures are in place that will avoid the death of animals from this activity? Several fish are known to spawn or utilize as a nursery the area proposed for sand borrow. What, if any, precautions will be used to avoid impacts to the spawning or nursery activities of any of these fishes?

If you have any further questions please call me at (302) 653-2880.

Sincerely,

Keith Clancy

Keith Clancy, Ecologist
Delaware Natural Heritage Program

cc: Ken Reynolds, Division of Fish and Wildlife

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
DIVISION OF SOIL AND WATER CONSERVATION
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

OFFICE OF THE DIRECTOR

TELEPHONE: (302) 739-4411

June 10, 1996

Mr. Robert L. Cailegari
Chief, Planning Division
Philadelphia District
U.S. Army Corps of Engineers
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390

Dear Mr. Callegari:

This letter is in regard to the Rehoboth Beach/Dewey Beach Interim Feasibility Study - Draft Feasibility Report and Draft Environmental Impact Statement dated October 1995. The plan recommended by this report was a beach nourishment project consisting of berm and dune restoration along approximately 13,500 linear feet of beach extending from near Surf Avenue in Rehoboth south through the Silver Lake area to the southern border of Dewey Beach, with tapered sections extending into Deauville Beach and North Indian/Indian Beach at the northern and southern ends, respectively. The proposed dune would have a top width of 25 feet at an elevation of +14 feet NGVD throughout the project area while the berm elevation would be at +8 feet NGVD with widths of 125 and 150 feet in Rehoboth Beach and Dewey Beach, respectively. The project would require placement of approximately 1.43 million cubic yards of sand for initial construction with 360,000 cubic yards anticipated for periodic renourishments every three (3) years over the 50 year life of the project. The sand for the project would be obtained from a 1,120 acre offshore borrow area located on the southern portion of Hen and Chickens Shoal.

Please be advised that we have reviewed the Draft Report and are in general agreement with the findings and recommended plan. We look forward to participating with you in the detailed planning, engineering, design and construction phases of this project. If you have any questions, please do not hesitate to contact me.

Sincerely,

John A. Hughes
Director

TOWN OF DEWEY BEACH

105 Rodney Avenue
Dewey Beach, DE 19971
302-227-6363 (Voice or TDD)
302-227-6580 Fax

William H. Rutherford
Town Manager

June 14, 1996

Mr. Robert L. Callegari
Chief, Planning Division
Philadelphia District
U.S. Army Corps of Engineers
Environmental Resources Branch
Wanamaker Building
100 Penn Square East
Philadelphia Pa 19107-3390

Dear Mr. Callegari:

Please let this letter serve as notice to you that the Commissioners of the Town of Dewey Beach, Sussex County Delaware have carefully reviewed the Rehoboth Beach/Dewey Beach Interim Feasibility Study as published by public notice No CENAP-PL-E-95-14 dated October 27, 1995, and do fully support the concept in its entirety.

Respectfully,

W Rutherford

William H Rutherford,
Town Manager

cc: R Henry/DNREC

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
DIVISION OF SOIL AND WATER CONSERVATION
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

OFFICE OF THE DIRECTOR

TELEPHONE: (302) 739 - 4411

June 18, 1996

LTC Robert P. Magnifico, PE
District Engineer
Philadelphia District
U.S. Army Corps of Engineers
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390

Dear Colonel Magnifico:

This letter is in regard to the Rehoboth Beach/Dewey Beach Interim Feasibility Study - Draft Feasibility Report and Draft Environmental Impact Statement dated October 1995. The plan recommended by this report was a beach nourishment project consisting of berm and dune restoration along approximately 13,500 linear feet of beach extending from near Surf Avenue in Rehoboth south through the Silver Lake area to the southern border of Dewey Beach, with tapered sections extending into Deauville Beach and North Indian/Indian Beach at the northern and southern ends, respectively. The proposed dune would have a top width of 25 feet at an elevation of +14 feet NGVD throughout the project area while the berm elevation would be at +8 feet NGVD with widths of 125 and 150 feet in Rehoboth Beach and Dewey Beach, respectively. The project would require placement of approximately 1.43 million cubic yards of sand for initial construction with 360,000 cubic yards anticipated for periodic renourishments every three (3) years over the 50 year life of the project. The sand for the project would be obtained from a 1,120 acre offshore borrow area located on the southern portion of Hen and Chickens Shoal.

Please be advised that we have reviewed the Draft Report and are in general agreement with the findings and recommended plan. We look forward to participating with you in the detailed planning, engineering, design and construction phases of this project.

There has been a significant amount of Congressional interest in the findings and status of the Rehoboth Beach/Dewey Beach interim feasibility report. We feel that the processing of the final feasibility report should proceed as far as possible, in case the future political environment proves more conducive to construction of this shore protection project.
As a conclusion to the processing of the final feasibility report we would like to proceed with the development and processing of a final Chief of Engineers report for transmittal to Congress. If you have any questions, please do not hesitate to contact me.

Sincerely,

John A. Hughes
Director

cf: The Honorable William V. Roth, Jr.
The Honorable Joseph R. Biden, Jr.
The Honorable Michael N. Castle

City of Rehoboth Beach

Office of the Mayor

229 Rehoboth Avenue, P.O. Box C
Rehoboth Beach, Delaware 19971

(302) 227-6181
Fax (302) 227-4643

June 19, 1996

Mr. Robert L. Callegari
Chief, Planning Division
Philadelphia District
U.S. Army Corps of Engineers
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390

Dear Mr. Callegari:

This letter is written regarding the Rehoboth Beach-Dewey Beach Interim Feasibility Study-Draft Feasibility Report and Draft Environmental Impact Statement dated October 1995.

The Commissioners of Rehoboth Beach have reviewed the report and we are in general agreement with the findings and support the concept of placing sand fill to provide storm protection. We look forward to working with you in the detailed planning and engineering phases to ensure the city's needs are met.

We would like to extend our sincere thanks to you and your staff for your efforts on behalf of the city. Should you have any questions please feel free to contact me at any time.

Sincerely,

Samuel R. Cooper

Samuel R. Cooper
Mayor

pgb
pc: Shawn Hanrahan, Army Corps of Engineers
John Hughes, DNREC
Commissioners

DEL-SG-05-94

RECREATIONAL BENEFITS OF DELAWARE'S PUBLIC BEACHES:

ATTITUDES AND PERCEPTIONS OF BEACH USERS AND RESIDENTS OF THE MID-ATLANTIC REGION

by

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A Report Prepared for:

Delaware Department of Natural Resources and Environmental Control
Division of Soil and Water Conservation
and the
U.S. Army Corps of Engineers, Philadelphia District

AUGUST 1994

University of Delaware
Sea Grant College Program
Newark, DE 19716

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ACKNOWLEDGMENTS

The authors wish to thank the DNREC Division of Soil and Water Conservation for their support of this study. In addition to the required willingness-to-pay responses that were collected and analyzed, much useful attitudinal information and user data also were gathered. These supplemental data will be presented to local community officials so that they can more fully understand the characteristics of beach visitors and better respond to their needs.

We are grateful for the many helpful comments and suggestions provided by Ms. Christine McVey, economist with the U.S. Army Corps of Engineers, Philadelphia District, and Mr. Robert Henry, Program Administrator of the Shoreline and Waterway Management Section of the DNREC Division of Soil and Water Conservation. Without their support and assistance, this study and final report would not have been possible.

We also wish to thank Ms. April Beauchamp with the University of Delaware Sea Grant Marine Advisory Service for all of her contributions in typing the many draft copies and final version of our survey instruments, as well as this completion report. Ms. Pamela Donnelly, Ms. Tracey Bryant, and Mr. David Barczak of the University's Marine Communications Office deserve thanks for their communications support during various phases of the project.

Dr. George Parsons, associate professor of marine policy of the University's Graduate College of Marine Studies, provided invaluable advice as we became more familiar with the contingent valuation method of valuing natural resources like ocean beaches. His comments were always constructive and helpful. Thanks are also extended to Mr. John Confer for assistance in conducting data analysis and Ms. Eileen Lodermeier for assisting with data entry.

We are grateful to those randomly selected mail survey respondents from throughout the region who took the time to answer our questionnaire and return it. Their responses were vital to the success of the study. Finally, we wish to thank the 562 on-site beach users who took the time to talk with us during the summer of 1993 and provide their opinions about our valuable ocean beaches. Their feelings, reflected in this report, will have an impact on the course of action for managing Delaware's ocean beaches for years to come.

EXECUTIVE SUMMARY

This report, *Recreational Benefits of Delaware's Public Beaches: Attitudes and Perceptions of Beach Users and Residents of the Mid-Atlantic Region*, provides an extensive analysis of ocean beach use by both Delaware residents and out-of-state visitors. The study was a cooperative effort of the Division of Soil and Water Conservation, Delaware Department of Natural Resources and Environmental Control (DNREC); the U.S. Army Corps of Engineers, Philadelphia District; and the University of Delaware Sea Grant Marine Advisory Service.

The study sought to determine beach users' and non-beach users' willingness-to-pay for using Delaware beaches, their attitudes toward beach replenishment efforts, and their willingness to contribute to a voluntary annual beach protection fund. Beach users were also asked about their motives for selecting certain Delaware beaches and their use patterns, their understanding of certain beach management practices, and support for various options for funding beach replenishment. Socio-economic information was also collected to better characterize the respondents.

A two-part study was initiated during the summer of 1993. The first component of the study included on-site interviews of 562 beach users at five Delaware ocean beach communities (Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany Beach, and Fenwick Island). The second component consisted of a mail survey of more than 1,000 residents living within a five-state regional area and the District of Columbia. After undeliverable questionnaires were accounted for, a total of 348 completed surveys were returned for a 39 percent response rate.

Initially, frequency data were obtained for each component of the study. In addition, in the on-site part of the study, responses from the five individual beach communities are presented and discussed. The mail-survey responses were also examined by whether respondents owned beach property or were non-beach property owners. There was also a small number of mail respondents (n=46) who indicated that they did not use Delaware ocean beaches. These individuals still provided useful opinions about whether they would support beach replenishment efforts.

The study findings revealed that on-site respondents were primarily residents of two states, Pennsylvania (28%) and Maryland (28%), with 16 percent being Delaware residents. The greatest percentage of mail respondents came from Delaware (38%)--Delaware residents were oversampled in the mail survey--and Maryland (26%). Most on-site visitors were visiting the Delaware beach area for one week or less (76%). Only 12 percent of the on-site respondents owned property in an ocean beach community, whereas 50 percent of mail respondents indicated that they owned beach property. (Beach property owners were also intentionally oversampled in the mail survey.)

When asked to indicate what attracted them to certain Delaware beaches, on-site and mail respondents voiced similar concerns. On a 1 to 5 scale (1 = strongly disagree and 5 = strongly agree), each group indicated the following attributes were especially important: "enjoying the visual qualities of the beach scenery" (both reporting 4.4 ratings), "engaging in beach-related activities" (4.4--on-site; 4.1--mail), "the town keeps the beach clean and attractive" (4.3--on-site; 4.2--mail), and "socializing with family, friends and others" (4.1--on-site; 4.2--mail).

The attributes that received the lowest ranking from both groups included: "to be with a large number of people" (2.2--on-site; 1.8--mail); "the availability of public restrooms" (2.7 for both groups); and "there is adequate parking" (3.0 for both groups). On-site respondents also noted that solitude (2.8) was not an important attribute for them; mail respondents noted that the availability of beach rentals and concessions was not of primary importance to them (2.8).

On-site respondents were asked for their perceptions of beach crowding and how the number of people that were on the beach affected their enjoyment on the day they were interviewed. On a nine-point scale (1 = not at all crowded and 9 = extremely crowded), the average crowding rating was 4.7. Most of the respondents (46%) rated the crowding to be moderate (between 4 and 6); 32 percent rated it not crowded (between 1 and 3); and 23 percent rated the crowding to be heavy (between 7 and 9).

Even though 68 percent of the respondents rated the crowding to be moderate or heavy, the majority of all beachgoers indicated that this did not have a negative impact on their enjoyment of the beach. On a nine-point scale (1 = increased enjoyment and 9 = decreased enjoyment), the average enjoyment rating was 4.5. Sixty-five percent of all respondents indicated the number of people on the beach had no effect on their enjoyment (between 4 and 6); 26 percent indicated the number of people increased their enjoyment (between 1 and 3); and 10 percent reported that the number of people decreased their enjoyment (between 7 and 9).

On-site respondents were also given the opportunity to rate the overall enjoyment of their beach experience on a scale of 1 to 10, with 10 being a perfect day. On average, respondents rated their beach experience 8.4, indicating that most thought it was near perfect. Twenty-three percent of all respondents rated their beach experience on the day they were interviewed a perfect "10."

There were no noticeable differences between on-site respondents and mail respondents with regard to people's understanding of beach management techniques and attitudes toward sand replenishment. Using the same five-point scale that was discussed earlier, both groups ranked the statement "a wide sandy beach will protect beachfront property and preserve the coastal economy" the highest (3.9). This was followed by "sand replenishment should be used to maintain wide beaches" (3.8); "if I know the beaches are kept replenished with sand, it would give a sense of security to my family and me" (3.5--on-site; 3.6--mail); and finally, "jetties, groins and bulkheads are effective at slowing erosion" (3.4).

The questions that sought input on who should help pay for sand replenishment also exhibited no differences between the two groups. Both groups felt that state government (4.1--on-site; 4.0--mail) and local governments (4.1--on-site; 4.0--mail) should be the primary providers of funds to support beach nourishment. Both groups also felt strongly that everyone who uses and benefits from the beach should help support replenishment efforts (3.8--on-site; 4.0--mail). The least favored option for helping support beach replenishment was from the federal government (3.4--on-site; 3.5--mail).

Both groups were asked whether they would pay a certain amount (bid amounts varied between $1.00 and $5.00) for a day's use of the beach. Seventy-seven percent of the on-site respondents and 76 percent of mail respondents were willing to pay some amount per day to use the beach. The average amount that all on-site respondents were willing to pay was $3.01, and the average for all mail respondents was $2.85. For those who were not willing to pay a fee to use the beach, the following reasons were most often mentioned by both groups: they already paid through other means; they objected to the daily fee payment method; and they did not want to place a dollar value on the experience.

A second question asked of both groups sought to determine if they would pay a greater amount to use a beach that had been replenished with sand. Thirty percent of the on-site respondents and 21 percent of the mail respondents were willing to pay more to use a widened beach. The average willingness-to-pay was $3.70 for all on-site respondents and $3.50 for all mail respondents.

Seventy-nine percent of on-site respondents were willing to contribute to a voluntary annual beach protection fund which would insure the beaches would be maintained for their use as well as that of future generations. Of the mail respondents, only 34 percent indicated that they would contribute to an annual beach protection fund.

The average amount that all on-site users were willing to contribute to the hypothetical beach fund was $63.69. The amount of the contributions from those who were willing to contribute ranged between $3.00 and $2,500. On-site respondents who were not willing to contribute to the annual beach fund mentioned the following reasons for their reluctance: they already paid through other means; there was not enough information to make a decision; and they objected to the annual contribution method of payment.

The average amount that all mail respondents were willing to contribute was $26.60. The annual contributions from those willing to contribute ranged between $1.00 and $1,000. The 66 percent of the mail respondents who were unwilling to contribute mentioned the following reasons: they already paid through other means; there was not enough information to make a decision; and they could not place a dollar value on that type of beach protection.

Further analysis explored the differences among on-site respondents at individual beach communities. The differences with respect to most of the variables were very small or nonexistent. The additional analysis of mail survey respondents, which focused on beach property owners, non-property owners, and non-beach users exhibited many more differences when comparisons were made.

INTRODUCTION

Federal law mandates that the U.S. Army Corps of Engineers conduct an assessment of the economic benefits of coastal beaches prior to approving shoreline protection projects. For a project to be economically justified, the benefits associated with the project must be greater than its costs. The Delaware ocean shoreline is currently undergoing such an assessment. There are numerous elements that must be considered during the comprehensive evaluation. One important component of the assessment includes evaluating recreational beach use and determining beach users' willingness to pay (WTP) for beach enhancement.

As part of a cost share requirement by the Delaware Department of Natural Resources and Environmental Control (DNREC), Division of Soil and Water Conservation, the University of Delaware Sea Grant Marine Advisory Service was contracted to conduct the analysis of recreational beach users. The work undertaken had two distinct parts. The first part consisted of interviewing recreational beach users at five ocean beach communities during the summer of 1993. The second part of the study involved developing a survey and mailing it to 1,004 randomly selected residents within the Mid-Atlantic region. In total, 910 individuals provided responses through the on-site and mail survey efforts.

Both efforts were designed to help determine individuals' willingness to pay for a day on the beach (both with and without beach enhancement) and whether they would contribute to an annual beach protection fund. Questions were also designed to collect attitudinal information on why respondents visited selected beaches, to solicit information on their knowledge about certain beach management options, to determine how people would change their beach visitation patterns if user fees were imposed, and to collect necessary demographic information to accurately describe the study respondents.

The geographic setting for the study of Delaware beach visitors included Delaware oceanfront communities from Rehoboth Beach (at the northern end of the Delaware coastline) to Fenwick Island (at the southern end). The Delaware ocean coastline is approximately 24 miles long, and much of the land area is contained within state parkland. A series of municipalities and unincorporated communities are interspersed along the coastal barrier island.

The largest of the communities (from a population and tourism infrastructure perspective) is the town of Rehoboth Beach. It is a heavily developed town with many accommodations (hotels, cottages, and condos) and an active business community. There is a one-mile long boardwalk fronting the ocean beach.

While Dewey Beach is less developed than Rehoboth Beach to its north and Bethany Beach to the south, it still plays host to many summer visitors at cottages, motels, and condos. There are numerous eating establishments, and this community does not have a boardwalk fronting its coastline.

Bethany Beach is the second largest municipality. It is less developed than Rehoboth Beach, and more developed than Dewey Beach, and accommodates many thousands of summer visitors in its hotels, motels, condos, and beach cottages. The town also maintains a boardwalk along its oceanfront that is about one-half mile in length.

The two other communities that were included in the study (South Bethany and Fenwick Island) are somewhat different in character than the three previously mentioned ones. Beachfront cottages and houses dominate the landscape with much smaller business communities associated with them. The only significant business activity is contained along the major beach thoroughfare--Route 1 (Figure 1).

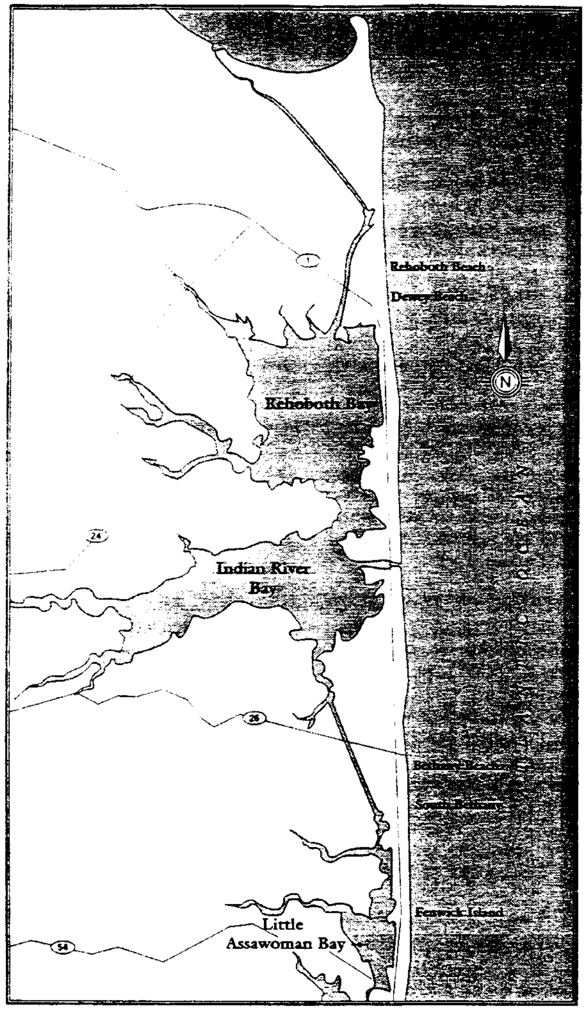


Figure 1. Map depicting Delaware ocean beach communities sampled during on-site component of study.

METHODS

Beachgoers in the five Delaware ocean beach communities were surveyed during the summer of 1993. Five hundred and sixty-two interviews were completed on 34 sampling days. The individual interview counts for each beach community were as follow: Rehoboth Beach--129, Dewey Beach--118, Bethany Beach--115, South Bethany Beach--96, and Fenwick Island--104. Seventeen percent of the interviews were conducted in June; 40 percent were conducted in July; and 43 percent were completed in August. Frequency data for all of the beach areas collectively were tabulated as were the individual data by beach community. Regression analysis and certain cross-tabulations were performed to further analyze and describe the respondents and their behavior.

A mail survey also was undertaken to collect additional information from both beach users and non-beach users. The sample of individuals who received the mail survey was generated in two ways. First, 200 individuals owning property in the five ocean beach communities were randomly selected from Sussex County tax maps. These individuals were targeted since the on-site survey did not provide a large sample of local property owners. This method insured that we would be able to ascertain the attitudes of this important segment of the population. Second, approximately 800 names and addresses of individuals living within a five-state area (plus the District of Columbia) were randomly generated by the private research firm, Survey Sampling Inc. (located in Fairfield, Connecticut).

Questionnaires were mailed to the resulting sample of 1,004 individuals on September 29, 1993. A postcard reminder (mailed October 8) and two complete follow-up mailings (mailed October 26 and November 2) took place for those who had not responded by these dates. After accounting for undeliverable mailings (e.g., no forwarding address, incomplete address, etc.), the effective sample was reduced from 1,004 to 895. Three hundred and forty-eight completed surveys were returned for a 39 percent response rate. The individual breakdown of surveys mailed and the response rate by area is as follows: Delaware beach property owners--200 mailed (73% response rate); Sussex County, DE--137 mailed (46% response rate); Kent and New Castle counties, DE--128 mailed (34% response rate); Pennsylvania--130 mailed (25% response rate); Maryland--130 mailed (26% response rate); Virginia--130 mailed (23% response rate); New Jersey--74 mailed (16% response rate); and the District of Columbia--75 mailed (33% response rate) (Table 1).

The questions asked of respondents in the field and the mail components of the study were constructed as similarly as possible. However, there are distinct differences between interviewing an individual in person in a field setting and mailing a questionnaire which asks people to respond to the same questions. Those administering the on-site surveys had the benefit of being able to more fully explain and discuss

Table 1. Mail questionnaire response rate by geographic location.				
Geographic Location	No. Original Mailing	No. Undeliverable	No. Responses	Percent Response (after undeliverables)
Delaware beach communities	200	4	144	73
Sussex County, Delaware	137	35	47	46
Kent/New Castle counties, Delaware	128	22	36	34
Pennsylvania	130	8	30	25
Maryland	130	11	31	26
Virginia	130	9	28	23
New Jersey	74	7	11	16
Washington, DC	75	11	21	33
TOTAL	1,004	107	348	39

portions of the survey if they were asked. In the mail survey, the written instructions for answering the questions had to be clear and concise. In addition, it was expected that a portion of the respondents to the mail survey would be non-users who had never had a Delaware beach experience.

Three fundamental differences were apparent with regard to administering the two surveys: (1) All of the individuals responding to the on-site interviews were visiting the Delaware beach area in 1993 and their responses were based on this time period. Mail respondents were asked to complete all of the questions on the survey instrument if they had visited a Delaware ocean beach at any time. Those who had never visited a Delaware beach were directed to skip certain questions that did not apply to them. (2) During the on-site interviews, many of the questions that were asked were specifically targeted to the beach the respondents were using. The mail survey respondents were asked to identify the beaches they had visited in Delaware and answer questions specific to the beach they considered to be their primary-use beach. There was no way to guarantee this direction was followed. (3) When on-site users were asked whether they would pay for an enhanced beach, two 8" x 10" colored photographs showing an unnourished beach and a nourished beach were used to elicit a response. Due to cost limitations, the mail survey respondents were sent the same two photos in black and white and only measuring 4-1/2" x 7" in size.

A question in both surveys asked if the wording of the questions that were asked was understandable. Respondents from both groups generally felt that the questions presented to them were clearly worded and understandable. However, on-site respondents (62%) were more likely than mail respondents (32%) to indicate that the questions were "very clear." Only 4 percent of the on-site group noted that the questions were "moderately clear," "unclear," or "very unclear" compared to 24 percent of the mail survey group. There were no apparent differences observed between beach communities or beach users in the two surveys regarding perceptions of question clarity (Tables 2 and 3).

Table 2. On-site respondents' perceptions of survey question clarity (percent).

Question Clarity	On-site Respondents					
	All (n=559)	Rehoboth Beach (n=128)	Dewey Beach (n=117)	Bethany Beach (n=115)	South Bethany (n=96)	Fenwick Island (n=103)
Very Clear	62	65	59	57	65	66
Clear	34	33	37	39	28	33
Moderately Clear	3	1	4	4	6	1
Unclear	1	2	0	0	1	0
Very Unclear	0	0	0	0	0	0

Table 3. Mail respondents' perceptions of survey question clarity (percent).

Question Clarity	All (n=336)	Beach Users: Non-Property Owners (n=150)	Beach Users: Property Owners (n=141)	Non-Beach Users (n=46)
Very clear	32	38	25	36
Clear	46	43	47	47
Moderately Clear	19	17	22	13
Unclear	3	1	5	2
Very Unclear	1	1	1	2

STUDY RESULTS

The study results are presented in a sequential fashion. Initially, respondents' socioeconomic (demographic) characteristics are presented--e.g., income, age, education, sex, etc. The next discussion provides a basic description of the respondents--e.g., state of residence, number of visits to the beach each year, visiting group size, length of time spent on beach, etc. Their attitudes about visiting the beach and understanding of beach management practices are presented next. Another section presents individuals' willingness to pay for visiting the existing beach, as well as their willingness to pay for an enhanced beach (replenished with sand to widen it). Last, individuals' willingness to contribute to an annual beach protection fund is explored.

In addition to overall frequency data for the sample of on-site beach users, results are provided by each beach community. For the mail survey respondents, overall frequencies are provided, as are frequencies for beach users (non-property owners and beach property owners) and non-beach users. In many instances where frequency data are provided, column totals may not equal 100 percent due to rounding.

Of the 348 respondents to the mail survey, 46 respondents indicated that they had never visited an ocean beach in Delaware. These individuals were still considered to be an important segment of "non-beach users" who could provide important information about their attitudes and perceptions related to beach management. They were instructed to complete the portions of the survey instrument that dealt with their attitudes about beach management, their willingness to pay for a day on a Delaware beach, both before and after sand renourishment, their demographic status, and their willingness to contribute annually to a beach protection fund.

Beach users in the mail survey were further segmented into coastal property owners and non-owners. There was a total of 150 non-property owning beach users. One hundred and forty one respondents in the mail survey owned property in the coastal communities. Of this total, 12 percent indicated that the property was their primary residence and 88 percent indicated that it was a secondary residence.

SOCIOECONOMIC CHARACTERISTICS

Employment

There were distinct differences between mail survey respondents and on-site respondents with regard to employment (Tables 4 and 5). Seventy-six percent of the on-site beachgoers were employed full time or part time versus 62 percent of the mail survey respondents. A further difference was noted with respect to retired individuals. Twenty-seven percent of mail respondents were retired compared to 8 percent of on-site respondents.

Individual beach communities exhibited some differences with regard to employment (Table 4). Eighty-nine percent of Dewey Beach respondents were employed full time or part time compared to Fenwick Island and Bethany Beach where 70 percent of the respondents were employed full or part time. Only 3 percent of Dewey Beach's respondents were retired compared to a high of 11 percent in Fenwick Island.

Notable differences were observed when comparisons were made between mail survey respondents (Table 5). Non-property owners (65%) were more likely to be employed full-time than either beach property owners (52%) or non-beach users (57%). Property owners (31%) had a greater tendency to be retired than either of the other two groups (24%--non-property owners; 22%--non-beach users). There was a greater percentage of non-beach users (13%) indicating that they were students, whereas only 1 percent of non-property owners indicated the same.

Education

The educational level of the two survey groups was fairly consistent. Sixty-nine percent of the mail respondents were college graduates, with 44 percent of them reporting post-graduate education (Table 5). Fifty-nine percent of the on-site beachgoers indicated that they had completed college, with 28 percent of them reporting further education (Table 4).

When beach communities in the on-site survey were examined, two-thirds of the South Bethany respondents were college graduates, with 38 percent reporting post-graduate education (Table 4). The community with the smallest number of college graduates was Fenwick Island (50%). In the other beach communities, between 55 percent and 67 percent of respondents reported that they were college graduates.

There was little difference with respect to education between different segments of the mail survey respondents (Table 5). The majority of all groups were well educated and college graduates. Seventy-seven percent of beach property owners were college graduates, which was slightly higher than non-property owners (63%) and non-beach users (74%).

Table 4. Descriptive profile of on-site respondents (percent).

	All (n=562)	Rehoboth Beach (n=129)	Dewey Beach (n=118)	Bethany Beach (n=115)	South Bethany (n=96)	Fenwick Island (n=104)
EMPLOYMENT						
Employed Full Time	65	68	75	61	64	55
Retired	8	9	3	6	8	11
Employed Part Time	11	8	14	9	10	15
Full-Time Homemaker	9	8	6	11	9	9
Student	6	4	2	10	4	9
Not Employed	2	2	0	2	4	1
Other	1	2	0	1	0	1
EDUCATION						
Some High School	2	0	2	4	2	4
High School Graduate	17	20	15	19	13	15
Some College	22	19	20	22	19	31
College Graduate	31	30	34	33	29	29
Post Graduate	28	30	30	22	38	20
AGE						
10-19	3	0	3	7	3	5
20-29	15	13	19	10	14	17
30-39	30	31	37	23	31	28
40-49	31	30	27	40	28	31
50-59	11	16	10	12	10	8
60-69	7	9	3	4	9	10
70+	3	2	2	4	4	2
INCOME						
Under $10,000	4	2	4	4	2	9
$10,000-19,999	3	2	4	5	1	1
$20,000-29,999	6	7	6	6	5	7
$30,000-39,999	12	12	13	10	10	14
$40,000-49,999	13	12	17	14	10	14
$50,000-74,999	30	37	23	22	37	33
$75,000-99,999	18	12	19	26	17	15
$100,000 & above	14	16	14	13	17	8
OTHER DEMOGRAPHIC VARIABLES						
Percent Married	74	78	64	78	80	70
Percent Male	43	46	44	41	40	42
Percent White/ Caucasian	97	95	98	96	99	99

Table 5. Descriptive profile of mail respondents (percent).				
		Beach Users		
	All (n=348)	Non-Property Owners (n=150)	Property Owners (n=141)	Non-Beach Users (n=46)
EMPLOYMENT				
Employed Full Time	58	65	54	57
Retired	27	24	30	22
Employed Part Time	4	2	6	4
Full-Time Homemaker	4	3	8	0
Student	2	1	0	13
Not Employed	<1	1	0	0
Other	4	5	3	4
EDUCATION				
Some High School	2	2	0	2
High School Graduate	13	17	7	13
Some College	16	18	16	11
College Graduate	25	22	27	33
Post Graduate	44	41	50	41
AGE				
10-19	1	1	0	2
20-29	3	1	0	16
30-39	17	24	7	20
40-49	23	26	21	20
50-59	22	22	27	16
60-69	16	12	22	16
70+	19	14	23	11
INCOME				
Under $10,000	3	4	0	8
$10,000-19,999	4	6	2	3
$20,000-29,999	6	6	5	8
$30,000-39,999	12	16	6	16
$40,000-49,999	12	11	12	16
$50,000-74,999	18	21	14	13
$75,000-99,999	14	11	16	18
$100,000 & above	32	24	45	18
OTHER DEMOGRAPHIC VARIABLES				
Percent Married	75	69	81	74
Percent Male	66	65	66	67
Percent White/Caucasian	96	97	99	84

Age

Respondents' ages were tabulated, and there was a significant difference between on-site and mail survey respondents. Most notable was the higher age of the mail respondents. Fifty-seven percent of the mail respondents were over the age of 50, versus 22 percent for the on-site beachgoers. Seventy-six percent of all on-site respondents were between the ages of 20-49, compared to 43 percent of the mail respondents.

When individual beach communities were examined from the on-site group, Rehoboth Beach had the greater percentage of individuals over age 50. Twenty-seven percent of this beach's respondents were over age 50. The "youngest" beach crowd was found in Dewey Beach, where only 15 percent of the respondents were over age 50 and 56 percent were between the ages of 20-39 (Table 4).

When age levels were examined, distinct differences between mail-sample segments were observed. Non-beach users were younger than both segments of beach users (Table 5). Eighteen percent of non-beach users were under 30 years of age, versus 2 percent of non-property owners. There were no beach property owners in the sample under 30 years of age. One-half of the non-property owners were between the ages of 30 and 49, compared with 28 percent of the property owners and 40 percent of the non-beach users. Forty-five percent of the beach property owners were greater than 60 years of age; however, this same age group accounted for only 26 percent of non-property owners and 27 percent of non-beach users.

Income

The income levels of mail survey respondents were somewhat higher than those of on-site beachgoers. Forty-six percent of the mail respondents reported incomes greater than $75,000, whereas 32 percent of on-site beach users reported similar incomes. Thirteen percent of each group reported income levels of under $30,000.

When income levels within individual communities in the on-site part of the study were examined, Bethany Beach respondents (39%) reported the highest percentage of people earning over $75,000; Fenwick Island beachgoers (23%) reported the lowest percentage of people earning this amount or greater. Fenwick Island respondents (17%) also reported the greatest percent of individuals earning less than $30,000. South Bethany (8%) included the fewest individuals with incomes under $30,000 (Table 4).

Non-beach users and non-property owning beach users reported lower average incomes than did beach property owners. For example, 16 percent of non-property owners and 19 percent of non-beach users reported incomes under $30,000. Only 7 percent of beach property owners reported incomes in this range. Sixty-one percent of beach property owners reported average incomes of greater than $75,000, whereas fewer non-property owners (35%) and non-beach users (36%) reported incomes at this level (Table 5).

Other Demographic Variables

Other demographic variables that were explored included marital status, sex, and race. No significant differences were found between marital status and race between the on-site and mail respondents. Seventy-five percent of on-site respondents were married, compared with 74 percent of mail respondents. Ninety-seven percent of on-site beachgoers were Caucasian, as were 96 percent of the mail respondents. More females (57%) were interviewed in the on-site portion of the study, compared with 66 percent of males completing the mail survey.

The only observable difference between these variables and the various beach communities was with respect to marital status. Only sixty-four percent of Dewey Beach respondents were married compared to 70 percent or greater for the other communities (Table 4).

The percent of married respondents showed little difference for all segments of the mail sample. Non-property owners (69%) were slightly less inclined to be married than the property owners (81%) or non-beach users (74%). There were no observed differences with regard to gender in the mail survey. About two-thirds of all groups of respondents were male. The race/ethnic variable exhibited noticeable differences, with beach property owners (99%) and non-property owners (97%) almost exclusively dominated by whites/Caucasians. Non-beach users responding to the mail survey reported greater ethnic diversity, with 84 percent indicating that they were white/Caucasian (Table 5).

State of Residence

Both on-site and mail subjects' permanent place of residence was recorded (Tables 6 and 7). The selection of on-site study subjects, with regard to residence, was completely random, with no knowledge of where the selected individuals resided. More than one-half of the on-site respondents lived in two states--Pennsylvania (28%) and Maryland (28%). Sixteen percent were Delawareans, and 9 percent were residents of Virginia. The mail sample consisted of a stratified random selection, with two distinct strata in Delaware (beach property ownership and remainder of state), four other states within the Mid-Atlantic region, and the District of Columbia. Thirty-eight percent of the mail respondents resided in Delaware, followed by Maryland (26%), Virginia (13%), and Pennsylvania (11%).

When individual beach communities were examined in the on-site component of the study, Rehoboth Beach (37%), Dewey Beach (31%), and Bethany Beach (30%) had more beach visitors from Pennsylvania than from any other state (Table 6). South Bethany Beach (33%) and Fenwick Island (32%) had the highest percentage of their beach users from Maryland. Delawareans were represented most often in Fenwick Island (24%) and Dewey Beach (20%).

Table 6. On-site respondents' state of residence (percent).						
State of Residence	All (n=562)	Rehoboth Beach (n=129)	Dewey Beach (n=118)	Bethany Beach (n=115)	South Bethany (n=96)	Fenwick Island (n=104)
PA	28	37	31	30	25	14
MD	28	28	18	29	33	32
DE	16	13	20	13	13	24
VA	9	7	13	8	10	9
NY	4	2	5	4	3	5
NJ	4	2	2	5	8	2
OH	2	2	3	1	1	4
CT	1	2	1	1	0	1
DC	1	1	2	2	0	1
Other	8	6	9	9	6	10

Table 7. Mail respondents' state of residence (percent).				
		Beach Users		
State of Residence	All (n=348)	Non-Property Owners (n=150)	Property Owners (n=141)	Non-Beach Users (n=46)
DE	38	48	35	7
MD	26	15	40	20
VA	13	13	13	20
PA	11	10	6	28
DC	7	11	1	9
NJ	4	2	1	17
NY	1	0	1	0
CT	1	1	1	0
Other	1	1	1	0

Non-beach users in the mail survey were mainly represented by residents from Pennsylvania (28%), Maryland (20%), Virginia (20%), and New Jersey (17%). Beach users were principally Delaware and Maryland residents. For non-property owners, 63 percent resided in these two states, with 34 percent residing in Virginia, Washington, DC, and Pennsylvania. For property owners, three-quarters of the respondents were residents of Delaware and Maryland.

Type and Length of Visit

Ninety-two percent of all the beachgoers who were interviewed on site were on an overnight stay in the local beach community. South Bethany (99%) had the greatest percentage of overnight visitors, and Rehoboth Beach (82%) had the lowest percentage (Table 8).

Seventy-six percent of all overnight visits were of short duration--one week or less; 13 percent were longer than one week. The remaining ten percent of beach users sampled were seasonal (8%) or permanent (2%) residents of the Delaware beach area. Dewey Beach (82%) and Rehoboth Beach (79%) were the communities most favored for short-duration visits, whereas Bethany Beach (17%) and South Bethany (15%) were most favored for longer visits. Most seasonal residents tended to reside in South Bethany (10%) and Fenwick Island (10%) (Table 8).

Table 8. Percent of on-site respondents who visited beach area overnight and length of stay.

Type of Visit	All (n=562)	Rehoboth Beach (n=129)	Dewey Beach (n=118)	Bethany Beach (n=115)	South Bethany (n=96)	Fenwick Island (n=104)
Percent on Overnight Visits	92	82	97	92	99	93

Length of Stay	All (n=517)	Rehoboth Beach (n=107)	Dewey Beach (n=113)	Bethany Beach (n=106)	South Bethany (n=94)	Fenwick Island (n=97)
Weekend Trip	1	2	1	2	2	0
Short Vacation (1 week or less)	75	79	82	67	72	75
Long Vacation (>1 week)	13	12	10	18	15	9
Seasonal Resident	8	7	6	9	10	10
Other*	2	0	1	5	1	5

* Includes those who own property and are full-time or part-time residents of beach community.

Residential Beach Property Ownership

Both on-site and mail respondents were queried as to whether they owned residential property in the Delaware beach area. The mail response was much higher since property owners were targeted in this component of the study. While 20 percent of the total mail sample were selected on the basis of property tax maps, 50 percent of the respondents reported that they were coastal property owners, suggesting that property owners were much more likely than others to respond to a survey on beach use and replenishment. Nine percent of the mail respondents noted this home was their primary residence and 41 percent indicated it was a seasonal residence. Twenty percent of the mail survey respondents owning property indicated that they offered it for seasonal or off-season rentals. Twelve percent of the on-site respondents indicated that they owned beach property, with 1 percent indicating it was their primary residence, and 11 percent noting it was a seasonal home (Table 9).

Table 9: Percent of on-site and mail respondents owning beach property (percent).

Own Beach Property	On-site Respondents (n=561)	Mail Respondents (n=346)
No Ownership	88	50
Own "Second" Home	11	41
Own "Primary" Home	1	9

Use of Delaware Beaches

Sixty-nine percent of on-site beach users reported visiting Delaware beaches every year; another 9 percent visit every other year; and 8 percent visit every two to five years (Table 10). Ten percent of those interviewed were first-time visitors to a Delaware ocean beach.

Mail respondents were asked when they last visited a Delaware ocean beach (Table 11). The majority (67%) of all respondents visited a beach in 1993 (the year the study was conducted). As might be expected, 100% of those who own coastal property visited an ocean beach in 1993. Non-property owners also reported visiting a Delaware ocean beach recently, with 78 percent having visited at some time during the 1990s (Table 11).

Mail respondents were instructed to indicate the number of days they spend on any Delaware ocean beach in an average year. Rehoboth Beach was by far the most popular beach to visit by mail respondents; it was visited by 35 percent of the sampled residents of the Mid-Atlantic region, followed by the three state park beaches--Cape Henlopen Park, Delaware Seashore State Park and Fenwick Island State Park--(28%), Bethany Beach (22%), Dewey Beach (18%), Fenwick Island (14%), South Bethany Beach (12%), and "other" ocean beaches (2%) (Table 12).

Table 10. On-site respondents' number of visits to Delaware beach area (percent).

How Often Visit Delaware Beaches	All (n=560)	Rehoboth Beach (n=129)	Dewey Beach (n=117)	Bethany Beach (n=115)	South Bethany (n=95)	Fenwick Island (n=104)
First Visit	10	11	11	10	6	9
Every Year	69	61	64	79	70	74
Every Other Year	9	12	10	5	12	6
Every 2-5 Years	8	10	12	2	10	9
Less than Every 2-5 Years	4	5	3	4	3	3

Table 11. Mail respondents' year of last visit to a Delaware ocean beach (percent).

		Beach Users	
Year of Visit	All (n=332)	Non-Property Owners (n=143)	Property Owners (n=141)
1993	67	57	100
1992	6	13	0
1991	2	4	0
1990	2	4	0
1980s	8	18	0
1970s	2	4	0
1960s	<1	0	0
1950s	0	0	0
1940s	<1	1	0
Never Visited	14	0	0

Table 12. Beach areas visited by mail respondents.		
Beach	**Percent Who Visited**	**Average No. Days Visited/Year**
Rehoboth Beach	35	28
Bethany Beach	22	30
Dewey Beach	18	35
Fenwick Island	14	37
Cape Henlopen State Park	13	6
South Bethany	12	33
Delaware Seashore State Park	10	9
Fenwick Island State Park	5	17
Other Ocean Beaches	2	13

The beach communities of Fenwick Island (37 days), Dewey Beach (35 days), South Bethany (33 days), Bethany Beach (30 days), and Rehoboth Beach (28 days) received the highest average number of days' visitation by mail respondents, possibly reflecting the higher incidence of property owners who spent substantial time on their local beaches.

On average, beach visitors in the on-site survey spent 16.7 days per year on Delaware's ocean beaches (Table 13). Thirty percent spent between one and five days per year on the beaches, and 34 percent spent between six and ten days. Seven percent of those interviewed in person spent more than 50 days per year on Delaware's ocean beaches. Those sampled at Bethany Beach and Fenwick Island generally reported spending the most days at the beach–19.2 and 21.5 days per year, respectively (Table 13).

The average number of days spent on the beach was 36.5 days for all mail respondents. About one-half (48%) visited fewer than ten days per year. Twenty-seven percent spent more than 30 days on Delaware beaches. As one would imagine, property owners (56.7 days) showed a much larger average number of days visiting than non-property owners (18.6 days). Forty-seven percent of property owners spent more than 30 days per year on Delaware beaches compared with 9 percent of non-property owners (Table 14).

Table 13. Average number of days spent on Delaware beaches annually by on-site respondents (percent).

Number of Days Spent on Delaware Beaches	All (n=560) (avg.=16.7)	Rehoboth Beach (n=129) (avg.=13.3)	Dewey Beach (n=118) (avg.=13.7)	Bethany Beach (n=115) (avg.=19.2)	South Bethany (n=96) (avg.=16.6)	Fenwick Island (n=104) (avg.=21.5)
1-5	30	42	37	25	17	22
6-10	34	29	31	37	43	34
11-20	16	12	13	17	22	17
21-30	8	9	9	7	6	9
31-50	6	5	7	8	5	5
51-90	6	3	4	6	5	11
>90	1	1	0	3	1	3

Table 14. Average number of days spent on Delaware beaches annually by mail respondents (percent).

		Beach Users	
Number of Days Spent on Delaware Beaches	All (n=196) (avg.=36.5)	Non-Property Owners (n=99) (avg.=18.6)	Property Owners (n=93) (avg.=56.7)
1-5	30	53	4
6-10	18	16	19
11-20	11	10	12
21-30	14	12	17
31-50	9	3	16
51-90	9	2	16
>90	9	4	15

Typical Group Size

Enjoying Delaware's recreational beaches is definitely a group activity. Overall, only 6 percent of on-site users interviewed were alone (Table 15). Forty percent of on-site visitors were in groups of two to three people. Another 28 percent were in group sizes of four to five. Thirteen percent were in groups of eight or more people. Fenwick Island beach visitors (10%) were most likely to visit the beach alone, while Rehoboth

Beach visitors (2%) were the least likely to visit alone. Rehoboth Beach respondents, however, did report the smallest average group size (3.5 people per group). South Bethany respondents visited the beach in the largest groups, with 38 percent indicating they visited with six or more people. Only 13 percent of Rehoboth Beach respondents reported being in groups of more than six people.

Fourteen percent of mail survey respondents reported spending time on the beach alone. Forty-nine percent of the respondents reported visiting the beach in groups of two to three people. Twenty-seven percent reported visiting Delaware beaches in groups of four to five. Four percent reported that they typically visit Delaware beaches with eight or more people in their group (Table 16). Beach property owners tended to visit the beach in slightly larger group sizes than non-property owners (15% vs. 6% in groups of six people or more).

Table 15. On-site respondents' typical beach group size (percent).

No. of People in Beach Group	All (n=562) (avg.=4.4)	Rehoboth Beach (n=129) (avg.=3.5)	Dewey Beach (n=118) (avg.=4.4)	Bethany Beach (n=115) (avg.=4.6)	South Bethany (n=96) (avg.=5.4)	Fenwick Island (n=104) (avg.=4.6)
1	6	2	5	9	7	10
2-3	40	54	38	39	32	35
4-5	28	31	32	30	22	24
6-7	13	10	11	10	17	16
8-9	6	2	7	4	9	7
10-11	4	1	6	4	6	6
>11	3	0	1	5	6	3

Table 16. Mail respondents' typical beach group size (percent).

		Beach Users	
No. of People in Beach Group	All (n=277) (avg.=3.3)	Non-Property Owners (n=135) (avg.=3.0)	Property Owners (n=136) (avg.=3.6)
1	14	16	10
2-3	49	52	46
4-5	27	26	29
6-7	6	2	10
8-9	2	1	3
10-11	1	1	1
>11	1	2	1

Time Spent on Beach

The average number of hours spent on the beach by on-site visitors was 4.7 hours. Forty-seven percent of all respondents spent between two and four hours on the beach; another 48 percent spent between five and seven hours (Table 17). There were no significant differences observed between visitors at the various beach communities. The amount of time spent on the beach was not asked in the mail survey.

Table 17. Number of hours spent on beach by on-site respondents (percent).

No. of Hours Spent on Beach (day of interview)	All (n=562) (avg.=4.7)	Rehoboth Beach (n=129) (avg.=4.7)	Dewey Beach (n=118) (avg.=4.9)	Bethany Beach (n=115) (avg.=4.8)	South Bethany (n=96) (avg.=4.6)	Fenwick Island (n=104) (avg.=4.7)
2-4	47	50	39	49	53	46
5-7	48	47	57	44	42	51
8-10	5	3	4	7	5	3

Reasons for Beach Selection

Those respondents who used Delaware beaches were instructed to rate the importance of certain attributes when visiting their favorite ocean beach. Both on-site respondents and mail respondents ranked many of the factors for visiting Delaware beaches the same. A five-point scale was used, with "1" indicating that they strongly disagreed with the statement that was presented to them and "5" indicating that they strongly agreed with it.

On-site respondents attached the most importance to enjoying the visual qualities of the beach scenery and engaging in beach-related activities (4.4 each on the five-point scale), a clean and attractive beach (4.3), closeness to the beach (4.2), and socializing with others (4.1). The least important beach attributes were the desire to be with a large number of people (2.2), followed by having public rest room facilities (2.7), and solitude (2.8) (Table 18).

There were very few differences in the data collected for various attributes from respondents at different beach communities. The only distinct differences were observed with respect to the two attributes, "There are adequate beach rentals and concessions" and "There are public rest room facilities." These differences between the community responses were understandable since certain communities had concessions and rentals (Rehoboth Beach, Dewey Beach, and Bethany Beach) and rest room facilities (Rehoboth Beach and Bethany Beach) at their beaches and others did not.

Mail respondents rated enjoying the visual qualities of the beach scenery (4.4) as their top attribute, followed by socializing with others (4.2), a clean and attractive beach (4.2), and engaging in beach-related activities (4.1). The least important attributes for mail respondents were the desire to be with a large number of people (1.8), followed by having public rest room facilities (2.7) and having adequate concessions and rentals (2.8) (Table 19).

Most property owner and non-property owner beach attribute ratings varied only slightly. Major differences were observed with regard to the attribute, "It is close to where I stay on vacation," which was rated higher by property owners (3.8) than by non-property owners (2.9). Non-property owners attached greater importance to the attributes, "There is little or no cost to enjoy it" (3.5 vs. 3.1); "There is adequate parking" (3.2 vs. 2.8); "There are adequate beach rentals and concessions" (3.0 vs. 2.5); and "There are public rest rooms available" (3.2 vs. 2.0).

Table 18. On-site respondents' reasons for visiting Delaware beaches (rank and percent).

Reason for Visiting Delaware Beaches	All (n=530)*		Rehoboth Beach (n=127)		Dewey Beach (n=113)		Bethany Beach (n=112)		South Bethany (n=88)		Fenwick Island (n=91)	
To enjoy visual qualities of beach scenery	4.4[1]	97.1[2]	4.4	96.9	4.5	98.3	4.4	94.8	4.5	97.9	4.5	98.1
To engage in beach-related activities	4.4	95.2	4.4	96.1	4.4	92.4	4.3	93.8	4.5	96.9	4.5	97.1
The town keeps beach clean/attractive	4.3	92.8	4.4	96.1	4.0	88.9	4.3	92.2	4.3	92.6	4.4	94.1
To socialize with family/friends/others	4.1	89.6	4.1	89.2	4.1	87.3	4.1	90.4	4.3	93.7	4.0	88.3
It's close to home or where I am staying	4.2	86.4	3.9	81.3	4.1	84.7	4.2	88.7	4.3	88.4	4.3	90.3
It's wide enough to enjoy activities	3.9	84.9	3.8	82.1	3.7	79.4	3.9	81.1	4.1	90.5	4.2	93.9
Little or no cost to enjoy it	3.9	76.2	3.9	73.4	3.9	72.9	3.9	78.8	3.9	74.8	4.0	81.5
There are adequate beach rentals and concessions	3.2	52.2	3.6	70.5	3.3	53.7	3.5	63.0	2.4	26.4	2.5	24.3
There is adequate parking	3.0	41.6	3.1	49.2	2.4	23.8	3.3	53.8	3.2	47.5	2.9	38.1
For solitude (to be alone)	2.8	36.7	2.7	31.0	2.6	30.5	2.8	33.0	3.1	44.8	3.1	47.1
There are public rest room facilities	2.7	32.5	3.2	47.5	2.1	5.1	3.1	50.0	1.9	12.2	2.2	11.5
To be with a large number of people	2.2	18.2	2.1	14.8	2.4	22.0	2.2	18.2	2.2	20.8	2.0	15.5

* n's are based on average number of responses to each statement.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

Table 19. Mail respondents' reasons for visiting Delaware beaches (rank and percent).						
			Beach Users			
	All (n=257)*		Non-Property Owners (n=128)		Property Owners (n=126)	
To enjoy visual qualities of beach scenery	4.4[1]	95.7[2]	4.4	97.0	4.5	94.9
To socialize with family/friends/others	4.2	90.9	4.1	89.6	4.3	92.6
The town keeps beach clean/attractive	4.2	90.0	4.1	88.6	4.3	92.4
To engage in beach-related activities	4.1	85.4	4.0	81.7	4.2	85.4
It's wide enough to enjoy activities	3.8	74.2	3.8	74.2	3.8	75.6
For solitude (to be alone)	3.5	60.2	3.5	60.8	3.5	60.8
Little or no cost to enjoy it	3.3	55.6	3.5	63.6	3.1	46.8
It is close to where I stay on my vacation	3.3	55.4	2.9	41.7	3.8	70.7
It is close to my primary residence	3.1	52.8	2.9	45.3	3.3	59.2
There is adequate parking	3.0	44.9	3.2	53.9	2.8	34.8
There are adequate beach rentals and concessions	2.8	37.5	3.0	41.8	2.5	32.2
There are public rest room facilities	2.7	34.8	3.2	52.4	2.0	12.7
To be with a large number of people	1.8	9.8	1.9	13.5	1.6	4.8

* n's are based on average number of responses to each statement.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

Perceptions and Impacts of Crowding

Those individuals who were interviewed during the on-site part of the study were asked to respond to their perceptions of crowding and how the number of people that were on the beach affected their enjoyment of the beach that day. A nine-point scale was used to estimate crowding with a "1" denoting not at all crowded and a "9" denoting extremely crowded. The average crowd rating was 4.7. This estimate varied between beach communities with Fenwick Island respondents assigning an average rating of 3.2 for crowding and Bethany Beach respondents, on average, rating the crowding at 5.8. Most of the respondents (45%) rated the crowding to be moderate (between 4 and 6); 32 percent rated it not crowded (between 1 and 3); and 23 percent rated the crowding to be heavy (between 7 and 9) (Table 20).

Table 20. Perceptions of crowding by on-site respondents (percent).

Crowding at Beach*	All (n=560) (avg.=4.7)	Rehoboth Beach (n=128) (avg.=5.7)	Dewey Beach (n=118) (avg.=4.7)	Bethany. Beach (n=115) (avg.=5.8)	South Bethany (n=95) (avg.=3.5)	Fenwick Island (n=104) (avg.=3.2)
1-3	32	12	30	11	53	62
4-6	45	47	51	52	37	38
7-9	23	42	20	37	11	1

* Based on 1-9 scale, with 1 = not at all crowded and 9 = extremely crowded.

Even though 68 percent of the on-site respondents rated the crowding to be moderate or heavy, the majority of all beachgoers indicated that this did not have a negative impact on their enjoyment of the beach. Beachgoers were asked whether the number of people on the beach impacted their enjoyment. Again, a nine-point scale was used with a "1" signifying that the number of people increased their enjoyment and a "9" indicating it decreased their enjoyment.

The average crowd impact/enjoyment rating was 4.5. Sixty-five percent of all respondents indicated the number of people on the beach had no effect on their enjoyment (between 4 and 6); 26 percent indicated the number of people increased their enjoyment (between 1 and 3); and 10 percent reported that the number of people decreased their enjoyment (between 7 and 9) (Table 21).

Table 21. Impact of crowding on beach enjoyment by on-site respondents (percent).

Impact of Crowding on Enjoyment*	All (n=561) (avg.=4.5)	Rehoboth Beach (n=129) (avg.=4.9)	Dewey Beach (n=118) (avg.=4.4)	Bethany Beach (n=114) (avg.=5.1)	South Bethany (n=96) (avg.=4.0)	Fenwick Island (n=104) (avg.=4.0)
1-3	26	19	27	.9	40	38
4-6	65	67	64	79	56	57
7-9	10	15	9	12	4	6

* Based on a 1-9 scale, with 1 = increased enjoyment and 9 = decreased enjoyment.

<u>Rating the Beach Experience</u>

On-site respondents were also given the opportunity to rate their overall beach experience on a scale of 1 to 10, with 10 being a perfect experience. It was up to the beachgoers themselves to determine what qualities they wanted to include in arriving at their rating. Overall, on average, respondents rated their beach experience 8.4, indicating that most thought it was near perfect. Fenwick Island visitors (8.6) had the highest average rating and South Bethany Beach visitors (8.2) the lowest. Twenty-three percent of all respondents rated their beach experience on the day they were interviewed a perfect 10. Fenwick Island beachgoers had the most perfect scores, with 30 percent indicating they were totally satisfied with their day on the beach (Table 22).

Table 22. Beach experience rating by on-site respondents (percent).

Beach Experience Rating*	All (n=562) (avg.=8.4)	Rehoboth Beach (n=129) (avg.=8.4)	Dewey Beach (n=118) (avg.=8.4)	Bethany Beach (n=115) (avg.=8.5)	South Bethany (n=96) (avg.=8.2)	Fenwick Island (n=104) (avg.=8.6)
1	<1	0	0	0	1	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	1	2	1	0	0	1
5	3	2	3	4	2	2
6	2	2	2	1	6	2
7	10	9	7	11	14	9
8	36	37	45	30	32	34
9	25	26	21	33	21	23
10	23	22	21	20	23	30

* Based on a 1-10 scale, with 10 = perfect.

Attitudes toward Beach Management and Sand Replenishment

There were no observed differences between on-site respondents and mail survey respondents with regard to people's understanding of beach management techniques and their attitudes toward sand replenishment, in particular. Using the same five-point scale that was previously discussed, both groups ranked the statement, "a wide sandy beach will protect beachfront property and preserve the coastal economy," the highest (3.9--on-site; 4.0--mail). This was followed by "sand replenishment should be used to maintain wide beaches" (3.8); "if I know the beaches are kept replenished with sand, it would give a sense of security to my family and me" (3.5--on-site; 3.6--mail); and, finally, "jetties, groins, and bulkheads are effective at slowing erosion" (3.4) (Tables 23 and 24).

No differences between on-site respondents in the beach communities were observed with regard to beach management and sand replenishment techniques. In the mail survey, beach users, both non-property owners and property owners, rated almost every statement higher than non-beach users, the one exception being the technique "Jetties, groins, and bulkheads are effective at slowing erosion." Property owners had the least support for this technique at slowing erosion.

Table 23. On-site respondents' understanding of beach management and sand replenishment (rank and percent).												
Understanding of Beach Management/ Sand Replenishment	**All (n=559)***		**Rehoboth Beach (n=128)**		**Dewey Beach (n=118)**		**Bethany Beach (n=115)**		**South Bethany (n=96)**		**Fenwick Island (n=103)**	
A wide, sandy beach will protect beachfront property and preserve the coastal economy	3.9[1]	82.5[2]	3.8	82.2	3.9	83.1	3.9	80.0	3.9	83.3	3.9	85.2
Sand replenishment should be used to maintain wide beaches.	3.8	76.6	3.8	79.9	3.8	75.5	3.8	73.1	3.8	77.1	3.8	77.6
If I know beaches are kept replenished with sand, it would give a sense of security to my family and me.	3.5	60.5	3.5	58.4	3.4	55.5	3.5	60.5	3.6	65.2	3.6	55.4
Jetties, groins, and bulkheads are effective at slowing erosion.	3.4	47.8	3.4	45.8	3.3	44.1	3.3	52.1	3.4	46.9	3.3	50.9

* n's are based on average number of responses to statements.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

Table 24. Mail respondents' understanding of beach management and sand replenishment (rank and percent).								
			Beach Users					
	All (n=323)*		**Non-Property Owners (n=138)**		**Property Owners (n=138)**		**Non-Beach Users (n=43)**	
A wide sandy beach will protect beachfront property and preserve the coastal economy	4.0[1]	76.7[2]	3.7	67.6	4.4	89.8	3.5	65.8
Sand replenishment should be used to maintain wide beaches	3.8	68.7	3.7	66.2	4.1	77.9	3.2	50.0
If I know the beaches are kept replenished with sand, it would give a sense of security to my family and me	3.6	57.6	3.2	44.2	4.3	81.5	2.8	32.6
Jetties, groins, and bulkheads are effective at slowing erosion	3.4	52.6	3.5	55.1	3.3	48.9	3.5	55.0

* n's are based on average number of responses to each statement.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

Support for Sand Replenishment Efforts

The questions that sought input on who should pay for sand replenishment also exhibited no significant differences between the two survey groups. Both groups felt that state government (4.1--on-site, 4.0--mail) and local governments--county and coastal towns (4.1--on-site; 4.0--mail)--should be the primary providers of funds to support beach nourishment. Both groups also felt strongly that everyone who uses and benefits from the beach should help support replenishment efforts (3.8--on-site; 4.0--mail). The least-favored option for supporting beach replenishment was the federal government (3.4--on-site; 3.5--mail) (Tables 25 and 26).

There were no observed differences between beach communities and respondents' support for sand replenishment in the on-site component of the study (Table 25). Beach property owners had a much stronger feeling about issues related to financially supporting beach replenishment efforts than did both non-property owners and non-beach users in the mail survey (Table 26).

Table 25. On-site respondents' support for sand replenishment of Delaware's beaches (rank and percent).

	All (n=561)*		Rehoboth Beach (n=129)		Dewey Beach (n=118)		Bethany Beach (n=115)		South Bethany (n=96)		Fenwick Island (n=104)	
State government should help support sand replenishment of Delaware's public beaches.	4.1[1]	89.4[2]	4.0	86.8	4.0	86.4	4.1	92.2	4.1	89.6	4.1	92.3
Local government (county and coastal towns) should help support sand replenishment of Delaware's public beaches.	4.1	89.3	4.1	89.9	4.1	87.3	4.1	90.4	4.1	89.6	4.0	89.4
Everyone who uses or benefits from the beach should help support beach replenishment efforts.	3.8	76.7	3.6	71.6	3.7	75.2	3.9	81.8	3.8	77.1	3.8	78.8
The federal government should help support sand replenishment of Delaware's public beaches.	3.4	57.2	3.3	54.3	3.4	60.2	3.4	54.0	3.5	58.4	3.5	59.2

* n's are based on average number of responses to all statements.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

Table 26. Mail respondents' support for sand replenishment of Delaware's beaches (rank and percent).								
			Beach Users					
	All (n=323)*		Non-Property Owners (n=138)		Property Owners (n=138)		Non-Beach Users (n=43)	
State government should help support sand replenishment of Delaware's public beaches	4.0	80.4	3.7	72.2	4.5	90.8	3.7	72.1
Everyone who uses or benefits from the beach should help support beach replenishment efforts	4.0	79.3	3.8	73.3	4.3	86.0	3.7	76.7
Local government (e.g., the county and coastal towns) should help support sand replenishment of Delaware's public beaches	4.0	78.6	3.8	73.2	4.3	88.2	3.6	72.1
The federal government should help support sand replenishment of Delaware's public beaches	3.5	58.5	3.3	51.8	4.1	73.1	2.6	34.1

* n's are based on average number of responses to each statement.
1 Rankings are based on a 1-5 scale, with 1 = strongly disagree and 5 = strongly agree.
2 Percentages are based on those respondents who "agreed" or "strongly agreed" to statement.

WILLINGNESS TO PAY

On-site Respondents

On-site beach users were asked two specific questions related to whether they would pay a daily fee to use the beach they were currently visiting. The first question asked if they would be willing to pay a specified amount (between $1 and $5) per person to use the beach they were using on the day they were interviewed. Bidded amounts were randomly assigned during each daily interviewing schedule.

If the beach users responded either affirmatively or negatively to the bidded amount, they were next instructed to state the maximum amount they would be willing to pay. Respondents could then provide an amount they felt they would pay (if different from the bidded figure they were assigned) or respond that they would be willing to pay nothing.

Seventy-seven percent of the on-site respondents were willing to pay some amount per day to use the beach (ranging between $.01 and $25.00). The mean willingness to pay for a day on the beach in its existing state (without sand replenishment) was $3.01

(Table 27). This average amount represents all respondents, including those who answered they would pay nothing.

Overall, for those who were not willing to pay a daily amount for using a Delaware ocean beach, the following reasons were mentioned: already pay through other means (61%); objected to daily per person user fee method (13%); did not want to place a dollar value on the experience (9%); not enough information (3%); that is what beach is worth (2%); objected to the way the question was presented (1%); and "other" reasons (12%).

Those respondents who were willing to pay a certain amount to use a Delaware beach were asked whether the number of trips they typically make to the beach would change if a daily fee was involved. Seventy-six percent of the respondents indicated that they would visit the beach as often as they currently do if a daily fee system was instituted (Table 27). The remaining 24 percent mentioned that they would go to the beach fewer times if a fee was imposed. Most of these respondents stated that they would make between one-third and one-half of the number of visits they currently make to the beach if such a fee were charged.

The second question that was asked sought to gain insight into what beachgoers would be willing to pay for an enhanced beach (with sand replenishment to widen the existing beach). Two colored 8" x 10" photographs were shown to each beach user. One photo revealed an eroded beach with little dry sand between beach users and the water; the second photo was of the same beach area after the beach had been replenished and widened with sand.

Respondents were asked whether they would be willing to pay more than the previous amount they had reported if the beach they were using was widened like in the replenished beach photo. Thirty percent of all the beach users indicated they were willing to pay more for the wider beach (Table 27). The willingness to pay for a day's use of the replenished beach ranged between $0.01 and $35.00 and averaged $3.70, or $0.69 more than for the existing beach. These amounts again represent all of the respondents, including those who answered they would pay nothing. The reasons individuals gave for not paying were quite varied. They included comments such as "beach width is not important," "already pay through taxes or other means," and "sand replenishment doesn't work." (See Appendix C for additional comments.)

Respondents were also asked how the number of visits they typically make to the beach would be affected if a user fee in the amount they reported for the wider ocean beach was implemented (Table 27). As in the case of the earlier question about the existing beach, most respondents (68%) stated that it would make no difference. About one-third (31%) reported that they would make fewer trips than now if the higher fee for the wider beach was imposed (compared to 24% if a fee were required for the existing beach).

Table 27. On-site respondents' willingness to pay for using current Delaware beaches, for wider beaches, and for annual beach protection fund.						
	All (n=562)	**Rehoboth Beach (n=129)**	**Dewey Beach (n=118)**	**Bethany Beach (n=115)**	**South Bethany (n=96)**	**Fenwick Island (n=104)**
Percent willing to pay some amount to use Delaware ocean beaches	77	80	79	75	74	78
Average amount willing to pay to use Delaware ocean beaches (zero amounts included)	$3.01	$3.22	$3.21	$2.73	$2.59	$3.20
How would fee affect number of visits typically made?						
More	0	0	0	0	0	0
Same	76	85	72	74	73	70
Fewer	24	15	28	26	27	30
Percent willing to pay more for wider beach	30	29	35	25	23	38
Average amount willing to pay for wider beach (zero amounts included)	$3.70	$3.90	$3.99	$3.36	$3.12	$4.02
How would wider beach fee affect number of visits typically made?						
More	1	4	0	0	0	2
Same	68	78	68	60	63	64
Fewer	31	18	32	40	37	34
Percent willing to contribute to annual beach protection fund	79	77	78	73	81	81
Average annual amount willing to pay to fund (zero amounts included)	$63.69	$55.34	$42.40	$95.44	$65.59	$61.42
Range of annual contribution to fund	$3-2,500	$3-500	$3-300	$5-2,500	$10-500	$5-500

As an additional payment vehicle, on-site visitors were asked whether they would contribute to an annual beach protection fund that would insure the beaches would be maintained for their use as well as for future generations. They were also informed that this contribution would be in addition to any daily user fees they might pay and that it would be voluntary. Approximately 79 percent of all respondents were willing to pay some annual amount ranging between $3.00 and $2,500 for long-term beach protection (Table 27). The reasons mentioned by the remaining 21 percent of respondents who said they would not contribute to the fund included the following: already pay through other means (34%); not enough information (11%); objected to the annual contribution method of payment (8%); objected to the way question was presented (4%); did not want to place a dollar value on that type of protection (3%); that is what the beach is worth (1%); and "other" reasons for not contributing to the fund (40%). (See Appendix E for additional comments.) The average amount respondents would contribute to the hypothetical annual fund was $63.69 when all responses (including zeros) are considered.

Beyond the overall response patterns discussed above, Table 27 also summarizes responses to the willingness-to-pay questions for individuals sampled at each of the five Delaware beach communities. There were some slight variations in responses to certain questions across beach locations. For example, while most beach users (74 to 80%) were willing to pay something at each of the Delaware beaches, the average amounts they were willing to pay for the existing beach were noticeably lower at South Bethany ($2.59) and Bethany Beach ($2.73) than at the other three locations ($3.20 to $3.22). The same pattern held true for the willingness to pay for the replenished beach; average values were lowest for Bethany and South Bethany beaches. In all cases, however, beach users were willing to pay at least $0.50 more for a day at a replenished beach compared to the existing beach, with the lowest difference ($0.53) at South Bethany and the greatest difference ($0.82) at Fenwick Island. Similarly, most beach users (73 to 81%) were willing to contribute something to the hypothetical beach protection fund. The average amounts respondents were willing to pay ranged from $42.40 for those at Dewey Beach to $95.44 for those at Bethany Beach.

As a final step in the analysis of willingness to pay for Delaware ocean beaches, comparisons were made to test for the existence of certain potential biases that could affect the results. More specifically, the willingness-to-pay measures were examined in relation to respondents' income and the amount of the starting bid. In addition, the potential influence of extreme values ("outliers") and "protest bids" were considered.

Analysis of responses by income category showed no significant difference across income levels for any of the three willingness-to-pay measures. Thus, willingness to pay for Delaware beaches was not a function of respondents' income levels. Similarly, analysis by the amount of the initial bid showed that although the average willingness to pay was higher when the bidded amount was higher, there was no statistically significant impact of the starting point on the final willingness to pay (Table 28). In other words, the mean willingness-to-pay values shown in Table 28 were not significantly different from each other.

Table 28. Percent of on-site respondents willing to pay bid amount and mean willingness to pay for existing beach.			
Bid Amount	No. Asked	Percent Willing to Pay Bid Amount	Mean Willingness to Pay ($)
$1.00	112	81	$2.87
2.00	112	64	2.60
3.00	113	49	2.95
4.00	113	40	3.04
5.00	112	46	3.57

Because the average willingness-to-pay estimates can be influenced by extreme values, it is instructive to look at these measures while adjusting for such values (Table 29). As noted earlier, the average amount respondents were willing to pay for a day at the existing beach was $3.01 per person. Nearly all responses were between zero and $10.00. Seven individuals, however, reported higher amounts of $15.00 (2), $20.00 (4), and $25.00 (1). If these "outliers" are removed from the calculation, the average amount people are willing to pay drops to $2.80 (Table 29).

Table 29. Mean willingness-to-pay values adjusted for outliers and protest bids: on-site survey.				
Willingness-to-Pay Measure	Overall Average	Normal Range of Responses	Average with Outliers Removed	Average with Protest Bids Removed
Daily Fee for Natural Beach	$3.01	$0-$10.00	$2.80	$3.85
Daily Fee for Enhanced Beach	$3.70	$0-$15.00	$3.46	$4.63
Voluntary Beach Protection Fund	$63.69	$0-$500.00	$55.74	$78.65

On the other hand, most of the zero values volunteered by respondents were "protest bids" in the sense that they did not represent what the individuals felt the resource was worth, but rather were the respondents' way of objecting to either the idea of charging fees or the specific details of the question. If these protest bids are removed from the calculation, the average willingness to pay for a day at the beach increases to $3.85 (Table 29).

Similarly, the "normal range" of responses to the value of a day at the enhanced beach was between zero and $15.00. Seven individuals reported higher values (six at

$20.00 and one at $35.00). If these values are considered outliers and removed from the computation, the average willingness to pay for the enhanced beach drops to $3.46. If the zero bids interpreted as protest bids are deleted, the willingness to pay for the replenished beach increases to $4.63, or $0.78 higher than the corresponding adjusted willingness to pay for the natural beach.

Finally, similar adjustments were made relative to the willingness-to-pay values for the hypothetical beach protection fund. The "normal range" of responses was between zero and $500.00, with only two higher values (one at $2,000 and one at $2,500). The average contribution respondents were willing to make to such a fund ($63.69 for all individuals) decreases to $55.74 with the two outliers removed, but increases to $78.65 with the protest bids deleted from the calculation (Table 29). As in the case of the other willingness-to-pay measures, these adjusted values give a better perspective on the amounts people are willing to pay and may represent a reasonable range of estimates for the various measures.

Further multiple regression analyses were conducted to determine what combinations of variables were related to subjects' willingness to pay for Delaware's ocean beaches. Because of the complexity of these analyses, these results are presented in Appendix B.

Mail Survey Respondents

Mail survey respondents were also asked whether they would be willing to pay a daily fee to use a Delaware ocean beach. User fee bid amounts ranging from $1 to $5 were presented to mail survey recipients. If they accepted or rejected the bid amount, they were then given the option of providing the maximum that they would be willing to pay to use a Delaware beach for a day.

Fifty-two percent of the overall sample were willing to pay the bidded amount that they were presented with, and 76 percent of the respondents indicated that they would pay some amount to use a Delaware ocean beach (Table 30). The overall sample of respondents was willing to pay an average of $2.85 (with zero amounts included) per person per day to use Delaware beaches. Eighty-three percent of the respondents who were willing to pay indicated they would take the same number of trips to Delaware ocean beaches if they had to pay for their use, while 14 percent said that they would take fewer trips and 3 percent indicated they would make more visits (Table 30).

For those not willing to pay any amount for using the beach, the most reported reason was that they already pay through other means (46%). Fifteen percent objected to the daily per person payment method, 9 percent felt there was not enough information to make their decision, 6 percent objected to the way the question was presented, 4 percent did not want to place a dollar value on the experience, and 2 percent stated that is what the beach is worth, and 18 percent suggested various "other reasons" why they would not be willing to pay.

Table 30. Mail respondents' willingness to pay for using current Delaware beaches, for wider beaches, and for annual beach protection fund.

		Beach Users		
	All (n=348)	Non-Property Owners (n=150)	Property Owners (n=141)	Non-Beach Users (n=46)
Percent willing to pay some amount to use Delaware ocean beaches	76	81	74	74
Average amount willing to pay to use Delaware ocean beaches (zero amounts included)	$2.85	$2.79	$2.97	$3.10
How would fee affect number of visits typically made?				
More	3	1	3	14
Same	83	84	79	86
Fewer	14	15	18	0
Percent willing to pay more for wider beach	21	13	30	23
Average amount willing to pay for wider beach (zero amounts included)	$3.50	$3.23	$3.98	$3.77
How would wider beach fee affect number of visits typically made?				
More	11	0	17	20
Same	77	80	74	80
Fewer	12	20	9	0
Percent willing to contribute to annual beach protection fund	34	31	42	23
Average annual amount willing to pay to fund (zero amounts included)	$26.60	$10.99	$51.64	$4.93
Range of annual contribution to fund	$1-1,000.00	$5-200.00	$1-1,000.00	$1-50.00

Twenty-one percent of the overall respondents indicated that they would be willing to pay more for a wider beach. The average amount they were willing to pay was $3.50 (with zero amounts included), or $0.65 more than for the natural beach. Those individuals who were not willing to pay more for a wider beach mentioned a variety of reasons for not doing so. They included such comments as "don't visit the beach often enough," "beach width is not important," and "already pay to use the beach." (See

Appendix D for additional comments.) Twelve percent of the respondents noted that they would make fewer visits with a widened beach, and 11 percent indicated that they would make more visits. Seventy-seven percent indicated they would make the same number of visits that they typically make if the user fee for the wider beach was imposed.

When mail respondents were asked whether they would contribute to an annual voluntary beach protection fund to insure that Delaware beaches are protected against erosion, 34 percent were willing to contribute to the fund (ranging from $1.00 to $1,000.00). The average amounts of the contribution, including those who said they would pay nothing, was $26.60 for the overall mail sample. The 66 percent of the sample who were unwilling to contribute offered the following reasons: already pay through other means (32%); there was not enough information to make a decision (14%), did not want to place a dollar value on that type of protection (14%); objected to the annual contribution method of payment (9%); objected to the way the questions were presented (5%); that is what the beach is worth (3%); and other reasons for not contributing to the fund (24%). (See Appendix F for additional comments.)

Only slight differences were observed between the various segments of mail survey respondents with regard to their willingness to pay some amount to use a Delaware ocean beach. It is understandable that non-property owning beach users (81%) and those beach users who owned property (74%) would be willing to pay for using the beaches, but 74 percent of non-beach users were also willing to pay some amount per day to use Delaware beaches. In addition the non-beach users' ($3.10) willingness to pay for a day on a Delaware beach was slightly higher than both beach user groups ($2.79--non-property owners; $2.97--property owners). More than three-quarters of all the groups (79%-86%) indicated that they would make the same number of visits to a Delaware ocean beach if they had to pay to use it. Fourteen percent of non-beach users, however, indicated that they would make more visits if a fee were imposed compared to only 1 percent of non-property owners and 3 percent of property owners (Table 30).

Non-beach users were more varied in their responses as to why they would not pay for using a Delaware ocean beach. The responses, "already pay through other means" and "objected to the daily per person payment method," were both mentioned by 21 percent of the non-beach users. Sixteen percent mentioned that they did not have enough information and 11 percent each mentioned that they did not want to place a dollar value on the experience or they felt that was what the beach experience was worth to them. Sixteen percent mentioned other reasons for being not willing to pay.

Only 13 percent of the non-property owners indicated that they would pay some additional amount for a wider beach. This was considerably lower than both property owners and (30%) and non-beach users (23%). They also indicated they would pay less on average for a wider beach than the two other groups ($3.23 vs. $3.98--property owners and $3.77--non-beach users). Eighty percent of both non-property owners and non-beach users indicated that they would visit the beach the same number of times that they currently do if they had to pay for a wider beach, versus 74 percent of property owners. If fees were imposed for a wider beach, non-property owners were the only group where none indicated they would visit the beach more than they typically do. In comparison, 17 percent of property owners and 20 percent of non-beach users reported that they would visit the beach more often than they typically do.

Beach property owners also reported the greatest difference in willingness to pay for the widened beach versus the natural beach. The average amount they were willing to pay for the replenished beach ($3.98) was about a dollar ($1.01) more than the amount they would pay for the natural beach ($2.97). The corresponding differences for non-property owners and non-beach users were $0.44 and $0.67, respectively (Table 30). These differences likely reflect the investment that beach property owners have in their properties, and the corresponding willingness to contribute to beach enhancements and protection efforts.

Beach users who did not own coastal property were more likely than non-users to support the hypothetical annual beach protection fund (31% willing to contribute an average of $10.93 vs. 23% willing to contribute an average of $4.93). Those who did own beach property, however, were much more likely to agree to contribute to the beach protection fund. Forty-two percent of the beach property owners were willing to contribute an average of $51.64 toward the fund.

An analysis similar to that conducted for on-site respondents was also performed for mail survey respondents to note whether responses differed based on the amount of the initial bids. The percent of mail respondents willing to pay decreased as bid amounts increased and the average dollar amount they were willing to pay was higher when the bid amount was higher. Like on-site respondents, however, there was no statistically significant impact of the starting point bid on the final willing-to-pay values (Table 31).

Table 31. Percent of mail respondents willing to pay bid amount and mean willingness to pay for existing beach.

Bid Amount	No. Asked	Percent Willing to Pay Bid Amount	Mean Willingness to Pay ($)
$1.00	75	69	$2.27
2.00	73	53	2.61
3.00	63	55	3.20
4.00	68	39	2.90
5.00	69	40	3.32

As was done for the on-site survey data, the willingness-to-pay values for the mail survey were adjusted for outliers and protest bids. There were only three outliers above the normal range of zero to $10.00 for the daily fee for the natural beach (two at $20.00 and one at $25.00). With these extreme values removed, the average willingness-to-pay amount decreased from $2.85 to $2.64 (Table 32). If the protest bids (all zero values except for the 2 percent who indicated that the beach had no value to them) are discarded, the average willingness to pay for a day at the beach increases to $3.66.

Table 32. Mean willingness-to-pay values adjusted for outliers and protest bids: mail survey.

Willingness-to-Pay Measure	Overall Average	Normal Range of Responses	Average with Outliers Removed	Average with Protest Bids Removed
Daily Fee for Natural Beach	$2.85	$0-$10.00	$2.64	$3.66
Daily Fee for Enhanced Beach	$3.50	$0-$15.00	$3.24	$4.29
Voluntary Beach Protection Fund	$26.60	$0-$500.00	$23.75	$44.55

There were three outliers above $15.00 for the willingness to pay for the enhanced beach (two at $20.00 and one at $30.00). With these outliers deleted, the average willingness to pay for the enhanced beach dropped from $3.50 to $3.24 (Table 32). In contrast, if the zero protest bids are deleted from the calculations, the willingness to pay for the replenished beach increases to $4.29, or $0.63 higher than the corresponding willingness to pay for the natural beach.

There was only one outlier ($1,000.00) above the normal range of $0 to $500.00 among mail survey respondents for the hypothetical beach protection fund. With this value deleted, the average contribution drops from $26.60 to $23.75 (Table 32). When protest bids are deleted from the annual beach fund calculation, the overall average contribution increases to $44.55. Again, the range of values for both the daily and annual payment mechanisms represents minimum and maximum estimates of the sample's willingness to pay for Delaware's ocean beaches.

CONCLUSIONS

This study examined the characteristics, behaviors, and attitudes among a broad cross-section of Delaware ocean beach users, as well as a segment of the population who has never visited a Delaware coastal beach. Based on a sample of individuals surveyed at five Delaware beach communities, Delaware beach users are primarily out-of-state visitors from Pennsylvania or Maryland who are on short vacations of one week or less. Most beach users visit a Delaware beach every year. They visit the beaches in groups, averaging 4.4 people and typically spend about 4.7 hours on the beach.

Beach visitors primarily select beaches to visit because of the scenery they offer, for the opportunity to engage in beach activities, to socialize with family and friends, and because municipalities keep the beaches clean and attractive. Factors that were less important included being with a large number of people and the availability of public rest rooms and parking facilities. The width of the beach was a moderately important factor among the various reasons for selecting a Delaware beach.

The majority of all respondents seemed to support sand replenishment efforts, but only about half felt that jetties, groins, and bulkheads are effective at slowing erosion. There was strong sentiment expressed that sand replenishment should be paid for by state and local government agencies, and less support for the federal government helping to pay for sand replenishment of Delaware's beaches. Most respondents agreed that everyone who uses or benefits from the beaches (those benefiting might include property owners or business owners located within the beach community) should help support beach replenishment efforts.

The major focus of the study was to determine economic values for individuals' use and enjoyment of Delaware's public ocean beaches. Although Delaware beach users currently pay no direct fees to use the beach, about three-fourths of all beach users surveyed indicated they would pay some amount (responses ranged from a low of .25/day to $25.00/day). This was a new concept to many beachgoers, and others attempted to relate it to the beach fee system currently in operation on New Jersey beaches. A key element, however, in presenting this question to beachgoers was in trying to have them place a dollar value on what their beach experience was worth and not actually thinking about paying a "user fee" each time they visited an ocean beach. Both on-site visitors and mail survey respondents indicated that they would be willing to pay about $3.00 per person for a day at the beach. Most respondents stated that the number of visits they make to the beach would not change if a daily user fee was implemented. Nearly all the respondents who were not willing to pay anything were classified as "protest bids," reflecting their lack of information about, or opposition to, the question rather than the value they actually attached to the beach.

A second key concept in administering the study was in trying to have respondents visualize what a replenished beach would look like. This was important since a second willingness-to-pay question sought their comments on paying additional fees for the widened beach. For on-site respondents, the approach employed was to have them visualize the beach they were currently using being widened, with the width being similar to a colored photograph they were shown and asking them what value they attached to it. About one-third of the on-site respondents indicated they were willing to pay more for a beach that had been widened with sand. Mail survey respondents had a somewhat more difficult time visualizing a widened beach since they were being asked to react to a smaller black-and-white photograph of a widened beach. Slightly more than one-fifth of mail respondents indicated that they would pay more for a wider beach. In both cases, the amount people were willing to pay showed an average increase of 23 percent over the amount they would pay for a natural beach.

A third area where economic input was solicited was in asking survey respondents if they would be willing to contribute to an annual beach protection fund. This concept was also difficult for some people since the question asked if they would contribute to the fund even if they never used the beach. This approach attempted to see whether individuals were willing to contribute financially "just to know the beaches would be maintained for their future use or future generations' use" (in economic terms this is known as existence value). There was a noteworthy difference between the on-site and mail survey respondents in their willingness to contribute to an annual beach protection fund. Approximately three-fourths of the on-site visitors were willing to contribute something to the fund, while only about one-third of the mail survey respondents were willing to do so.

It is conceivable that those who had never visited a Delaware ocean beach were less likely to respond to the mail survey. However, a sample of 46 non-users did respond and provided a somewhat different perspective of the data than did the sample of beach users. The non-users were less likely to feel that sand replenishment should be used to maintain wide beaches. Only one-half of the non-users agreed with this statement compared with three-quarters of the beach users who owned property and two-thirds of the non-property beach users.

Beach users and non-users alike generally agreed that the costs of sand replenishment should be supported mainly by state and local government agencies and by everyone who uses or benefits from the beach. The non-users were much less likely to feel that the federal government should help support sand replenishment of Delaware's public beaches. Only one-third of them voiced support for this option, whereas one-half of the non-property owners and almost three-quarters of the property owners felt that the federal government had a role in helping to replenish the state's beaches.

When beach users and non-beach users were asked whether they would be willing to pay for a day at the beach, there were no significant differences in the amounts they would pay for either the existing beach or an enhanced beach. Both groups were willing to pay more for a beach with sand replenishment when the payment vehicle was a hypothetical daily beach user fee. However, non-users were much less likely to contribute to an annual beach protection fund, again reflecting less of a vested interest in Delaware's beaches. These data reinforce the idea that enhanced beaches are worth more than unnourished beaches, but the costs of sand replenishment should be borne primarily by those who use and benefit from them.

The information presented in this report provides one small picture in the total feasibility analysis that will help the U.S. Army Corps of Engineers make decisions concerning future shoreline protection options for Delaware's public ocean beaches. When the willingness-to-pay responses of both beach users and non-users are tabulated and summarized, there appears to be a positive "consumer surplus" (an economic term that calculates the net benefits between an existing beach's value and the value it provides if it is replenished with sand). When the values of these recreation benefits are included in the total set of shoreline benefits (e.g., residential property values, value to businesses, etc.) and weighed against the total costs of the overall project, a cost-to-benefit ratio can be estimated. This final cost-benefit analysis will ultimately play a part in the U.S. Army Corps of Engineers' commitment to long-term enhancement and maintenance of Delaware's public beaches.

APPENDIX A

ANALYSIS OF RESPONSES BY

DELAWARE RESIDENTS VERSUS NON-DELAWAREANS

Introduction

Comparisons were made between Delaware residents and out-of-state respondents for both the on-site and mail components of the study. Most of the comparisons exhibited little difference between the two groups. However, Delaware residents (34 days/year--on-site; 42 days/year--mail) were inclined to use the beaches more frequently than non-residents (13 days/year--on-site; 2 days/year--mail) by a wide margin.

When demographic differences were examined, Delaware residents were slightly older (mail respondents only); and residents in the on-site survey had lower incomes and education levels than non-residents.

When beach attribute comparisons were analyzed, they were generally the same. A few significant differences were detected with regard to "being close to home" where residents (4.4--on-site; 3.4--mail) exhibited a higher rating than non-residents (4.1--on-site; 2.4--mail). "Being with a large number of people" was more important for residents responding in the on-site survey (2.4 vs. 2.2); non-residents in the mail survey indicated that the "availability of rest room facilities" (3.1 vs. 2.5) held greater importance.

Delaware residents were consistently more favorable toward the statements about beach management and sand replenishment, especially in the mail survey. Mail survey residents felt more strongly that sand replenishment should be used to maintain wide beaches (4.0 vs. 3.5); that a wide beach protects beachfront property and preserves the coastal economy (4.1 vs. 3.6), and sand replenishment provides security to their families (3.9 vs. 3.0).

Residents in the mail survey also felt more strongly that federal (3.9 vs. 2.8), state (4.2 vs. 3.6), and local (4.1 vs. 3.6) governments should help support sand replenishment. They also had stronger feelings than non-residents that everyone who uses or benefits from the beach should help support sand replenishment (4.2 vs. 3.7). Residents (3.7) surveyed on-site had stronger feeling about the federal government's role in helping support sand replenishment than did non-residents (3.4) surveyed in the field.

Willingness to Pay: On-Site Respondents

More significant differences between Delaware residents and out-of-staters were found with regard to their willingness to pay for using Delaware's ocean beaches. When the willingness-to-pay estimates are broken down by state of residence (Delaware residents versus non-Delawareans), the results indicate that out-of-state visitors ($3.16 and $3.88) were willing to pay more than Delaware residents ($2.20 and $2.72) for a day at the beach, both with and without an enhanced beach (Table A-1). Both residents and visitors were willing to pay significantly more for an enhanced beach. The difference in willingness to pay between the "with project" and "without project" amounts, however, did not differ significantly between residents ($0.52) and non-residents ($0.72).

On-site visitors were also asked whether they would contribute to an annual beach protection fund that would insure the beaches would be maintained for their use, as well as that of future generations. They were also reminded that this contribution would be in addition to any daily user fees that they might pay and that it would be voluntary. In contrast, Delaware residents were willing to pay much more for the hypothetical annual beach protection fund than non-residents ($125.39 versus $51.67 with $0 responses also included).

Table A-1. Average amounts that Delaware residents and out-of-state visitors are willing to contribute to beach nourishment (on-site survey respondents).

	Delaware Residents			Out-of-State Visitors			F-Value	Level of Significance
	n	Mean ($)	Standard Deviation ($)	n	Mean ($)	Standard Deviation ($)		
Willingness to pay-- without beach nourishment	91	2.20	2.49	469	3.16	3.30	6.9	.0087
Willingness to pay-- with beach nourishment	90	2.72	2.90	470	3.88	4.02	6.9	.0089
Willingness to contribute to annual beach protection fund	90	125.39	342.84	462	51.67	81.59	16.6	.0001

Willingness to Pay: Mail Respondents

When willingness-to-pay estimates are examined for Delaware residents and non-residents, the results show that those individuals living in other states ($3.46) were again willing to pay more than Delaware residents ($2.45) for a day at the beach in its current condition. While non-residents were also willing to pay more for an enhanced beach ($3.86 versus $3.25), this difference was small and not statistically significant (Table A-2). The difference between "with project" and "without project" amounts did differ significantly between residents and non-residents, with Delawareans' willingness to pay for an enhanced beach increasing more ($0.80 vs. $0.40). The increased amount that residents were willing to pay for the enhanced beach was twice as much as what non-residents were willing to pay.

Similar to the on-site data, Delaware residents were willing to contribute much more to the hypothetical beach fund than non-residents ($37.50 versus $5.55 with $0 amounts included). However, these amounts are substantially less than what the on-site respondents indicated they would contribute (Table A-2).

Table A-2. Average amounts that Delaware residents and out-of-state visitors are willing to contribute to beach nourishment (mail survey respondents).

	Delaware Residents			Out-of-State Visitors			F-Value	Level of Significance
	n	Mean ($)	Standard Deviation ($)	n	Mean ($)	Standard Deviation ($)		
Willingness to pay--without beach nourishment	173	2.45	2.99	110	3.46	3.65	6.5	.011
Willingness to pay--with beach nourishment	137	3.25	3.20	97	3.86	3.85	1.4	.230
Willingness to contribute to annual beach protection fund	226	37.50	98.97	117	5.55	14.10	12.0	.0006

APPENDIX B

REGRESSION ANALYSIS:

ESTIMATING BID FUNCTIONS FOR

ON-SITE AND MAIL SURVEY RESPONDENTS

Introduction

This appendix presents the results of a multiple regression analysis conducted to determine what variables could be used to predict or explain people's willingness to pay for beach recreation and enhancement efforts. The results are presented in separate sections for the on-site and mail survey components of the study because of the differing nature of the two samples and survey instruments. The on-site survey included only beach users sampled at five Delaware beach communities, and the personal interview instrument used included more potential predictor variables detailing the respondents' beach use patterns (e.g., group size) and perceptions (e.g., perceived crowding and satisfaction). The mail survey included both beach users and non-users, since part of the sample was drawn from the general population within several surrounding Mid-Atlantic states.

On-Site Respondents

Separate regression analyses were performed for each of the willingness-to-pay measures (pay daily fee for existing beach, pay daily fee for enhanced beach, contribute to voluntary annual beach fund) as dependent variables. Independent (or predictor) variables that were considered included the complete pool of demographic, beach use, and attitudinal variables which comprised the survey instrument. Step-wise regression was selected because of the exploratory nature of the analysis.

A stronger model was found for the annual beach protection fund variable than for the two daily fee payment vehicles. Twenty-eight percent of the variance in the annual beach fund measure was accounted for by four variables (the number of days spent per year on Delaware ocean beaches, the importance of choosing a beach with little or no cost [inverse relationship], importance of a beach offering solitude, and a 10-point rating for overall beach quality) (Table B-1). Thus, beach users willing to contribute more to a voluntary annual beach protection fund tended to be those who spent more days on the beach, those who attached less importance to selecting a beach with little or no cost, those who placed more value on solitude, and those who gave the beach they visited a higher quality rating.

The number of days spent on the beach each year played a much stronger role in the regression model than the other significant variables. This makes sense since it is logical that those who use a beach more would contribute more to a fund dedicated to preserving the beach. The opposite was found in the regression models for the daily fee payment vehicles (Tables B-2 and B-3). Beach users reporting that they spent more days on the beach were willing to pay a lower daily cost to use the beach. This, again, is not surprising since frequent beach users would be particularly impacted by such a payment vehicle and would likely seek out alternative means of access if daily user fees exceeded the amounts they were willing to pay.

Table B-1. Significant variables based on regression analysis for annual beach protection fund contribution (dependent variable).			
Independent Variables	**B**	**Beta**	**Level of Significance**
Number of days spent per year on Delaware ocean beaches.	3.5	.48	.0000
Importance of choosing a beach with little or no cost.	-18.6	-.13	.0056
Importance of beach for solitude.	15.8	.11	.0252
10-point rating for overall beach quality.	13.8	.11	.0263
Constant	-77.4		
R Square = .28			

Table B-2. Significant variables based on regression analysis for willingness to pay without beach nourishment (dependent variable).			
Independent Variables	**B**	**Beta**	**Level of Significance**
Number of days spent per year on Delaware ocean beaches.	-2.4	-.16	.0030
Importance of choosing a beach with little or no cost.	-41.2	-.15	.0090
Importance of beach being close to home or where I stay.	-36.9	-.12	.0300
Day or overnight visitor to beach area.	-165.8	-.15	.0090
Constant	973.7		
R Square = .09			

Table B-3. Significant variables based on regression analysis for willingness to pay with beach nourishment (dependent variable).			
Independent Variables	**B**	**Beta**	**Level of Significance**
Number of days spent per year on Delaware ocean beaches.	-2.9	-.15	.0050
Importance of choosing a beach with little or no cost.	-58.5	-.17	.0020
Marital status of beach visitors.	107.6	.11	.0360
Day or overnight visitor to beach area.	-179.6	-.13	.0170
Constant	863.7		
R Square = .08			

Mail Respondents

A similar analysis was conducted for the mail survey data set. The key difference here is that the respondents included non-beach users as well as Delaware beach users. Separate regressions were again performed for each of the willingness-to-pay measures (pay for existing beach, pay for enhanced beach, contribute to annual beach fund). These were used as the dependent variables and the full pool of potential explanatory variables available from the mail questionnaire were used as independent variables. Step-wise regression was selected because of the exploratory nature of the analysis. A stronger model was again found for the annual beach protection fund variable than for the two measures of willingness to pay for a day at the beach. Sixteen percent of the variance in the beach fund measure was accounted for by two variables (the number of days spent per year on Delaware ocean beaches and owning coastal property). Frequent beach users and those owning coastal property would contribute more to an annual beach protection fund (Table B-4).

Table B-4. Significant variables based on regression analysis for annual beach protection fund contribution (dependent variable).

Independent Variables	B	Beta	Level of Significance
Number of days spent per year on Delaware ocean beaches.	.26	.23	.0025
Coastal property ownership.	38.4	.26	.0006
Constant	-31.3		
R Square = .16			

These same two variables did not contribute to the explanation of the two daily willingness-to-pay measures (Tables B-5 and B-6). The only variables that contributed to predicting the amounts mail survey respondents were willing to pay for daily beach user fees were two beach attribute importance ratings. The importance of adequate concessions and rentals helped explain willingness to pay for a day at both the natural beach and the enhanced beach. Since this was a negative relationship, those placing less value on concessions and rentals would pay more for a day at the beach. The second predictor variable differed for the natural and enhanced beach models. For the natural beach (Table B-5), willingness to pay a daily user fee was greater for those attaching more importance to public rest room facilities. It is logical that people would pay more for a beach offering rest rooms than for a beach with no such facilities. For the enhanced beach (Table B-6), the importance of solitude was the second significant predictor variable. Those seeking solitude would pay more for a day at the enhanced beach, which makes sense since beach nourishment would increase the space available and the resulting sense of solitude on the beach.

Table B-5. Significant variables based on regression analysis for willingness to pay without beach nourishment (dependent variable).

Independent Variables	B	Beta	Level of Significance
Importance of adequate concession and rentals on beach.	-91.1	-.42	.0030
Importance of public rest room facilities on beach.	63.7	.29	.0350
Constant	360.5		
R Square = .06			

Table B-6. Significant variables based on regression analysis for willingness to pay with beach nourishment (dependent variable).

Independent Variables	B	Beta	Level of Significance
Importance of adequate concession and rentals on beach.	-77.8	-.31	.0020
Importance of beach for solitude.	53.3	.23	.0190
Constant	385.7		
R Square = .08			

Summary

The multiple-regression analyses suggest several points about people's willingness to pay for beach recreation and protection efforts. First, the frequency of using the beach influences willingness-to-pay bids, but in different ways for different payment vehicles. Regression models for both the on-site and mail survey data verified that people who use the beach more would contribute more to a voluntary beach protection fund. On the other hand, frequent beach users in the on-site survey would pay less for a daily beach user fee. Both of these findings reflect what one would expect to be the beach users' natural response based on protecting their interests and minimizing the impact on their participation. Second, coastal property ownership emerged as a strong predictor in the mail survey, which was designed to ensure adequate representation of property owners in the sample. Again, the effect is as expected, with property owners' greater willingness to contribute to beach protection reflecting their vested interests in their beach community properties. Third, much stronger models were found in both data sets for the annual beach protection fund as opposed to the daily user fee payment vehicles. Responses to the annual fund question are more explainable in terms of reasonable predictor variables than the responses to the daily fee questions. Finally, stronger regression models were found using the on-site data compared to the mail survey data, especially for the annual beach protection fund payment vehicle. (Variance explained was 28% for on-site data vs. 16% for mail data.) This difference may reflect the more heterogeneous nature of the mail survey sample (which included non-beach users, as well as beach users from throughout the Mid-Atlantic region), as well as a possible methodological effect resulting from the mail questionnaire versus personal interview approach.

APPENDIX C

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH–ON-SITE RESPONDENTS	
	No. Responses
WOULD NOT LIKE A WIDER BEACH	
Wider beach isn't worth paying more for than unreplenished beach	37
Like to be close to water	20
Don't like beach too wide	18
Like small beach with natural sand	4
Don't like to walk too far	1
Total	**80**
WIDTH IS NOT IMPORTANT	
Wider beach no effect on enjoyment	61
Wideness not important	2
Total	**63**
BEACH IS OKAY AT CURRENT WIDTH	
Okay as is	35
Wide enough as is	2
Width okay now for density of people in survey photo	1
Total	**38**
WOULD NOT USE DELAWARE BEACHES IF HAVE USER FEE	
Would go to different beach	22
Would do something else	6
Would stay in home state	2
Total	**30**
ALREADY PAY THROUGH OTHER MEANS	
Already pay through other means/with rentals	27
Contribute through other means	1
Total	**28**

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH--ON-SITE RESPONDENTS	
	No. Responses
WIDER BEACHES CAUSE INCREASED CROWDING	
Increased width would bring more people	18
Sand replenishment would increase crowds	2
Don't want a crowded beach	1
Beaches will still be crowded	1
Total	**22**
GOVERNMENT SHOULD PAY FOR WIDER BEACH	
State and federal government should support replenishment	9
Responsibility of state and towns	4
Towns should support sand replenishment	2
County should support sand replenishment	1
Total	**16**
AGAINST USER FEES	
Against daily user fees	7
Object to method of payment	7
Paying for beach makes me mad	1
Property owners should not pay	1
Total	**16**
BEACHES SHOULD BE FREE	
Beach should be free	12
Free access for Delaware residents	2
Public resource should be free	1
Total	**15**

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH–ON-SITE RESPONDENTS	
	No. Responses
SAND REPLENISHMENT IS NOT A GOOD IDEA	
Sand replenishment is bad idea/futile/no good alone	12
Sand replenishment not worth the cost	1
Rehoboth Beach will erode like Dewey Beach	1
Total	**14**
RATHER PAY THROUGH TAXES	
Should pay through taxes	9
Against beach fee, tax okay	1
Federal and state taxes should be used	1
Total	**11**
COULD NOT AFFORD TO PAY USER FEE	
Could not afford to visit	4
Retired on fixed income	2
On a limited income	1
Too many other expenses	1
Total	**8**
NEEDS MORE INFORMATION	
Not sure sand replenishment works	6
Needs additional information	1
Total	**7**
CROWDED BEACHES ARE OKAY	
Crowded beach is okay	1
Like being on beach with people	1
Total	**2**

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH-- ON-SITE RESPONDENTS	
	No. Responses
SHOULD NOT PAY FOR A WIDENED BEACH	
Should not pay for a widened beach	1
Should not pay for nature	1
Total	**2**
NATURE SHOULD CARE FOR BEACH	
Let nature care for beach	1
Nature will care for beach	1
Total	**2**
MISCELLANEOUS COMMENTS	
Not on beach often enough	4
Gentle slope is only concern	1
Surfing bad with sand replenishment	1
Likes using a wide beach	1
Number of users too small	1
Replenish to protect buildings and property	1
Total	**9**

APPENDIX D

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH– MAIL RESPONDENTS	
	No. Responses
NOT A FREQUENT DELAWARE BEACH USER	
Doesn't use beach often enough	18
Beach is not important to me	4
Lives out of state	2
Mainly visit beaches in other states	1
Lives too far away	1
Total	**26**
OPPOSED TO CONTRIBUTING TO A WIDER BEACH	
Beaches should be free	7
May go elsewhere if fee imposed	6
On fixed income; can't afford it	4
Fee would deter people from using Delaware beaches	3
Objects to per person user fee	1
Cost must be reasonable/accessible to all regardless of wealth	1
Might find alternate beach	1
Paying more would be burden on families	1
Total	**24**
BEACH WIDTH IS ADEQUATE	
Beach is wide enough	16
A wider beach wouldn't change a day at beach	2
User fee should be to maintain beach, not widen it	2
Total	**20**
ALREADY PAY TO USE THE BEACH	
Already pay through other means	15
Pay through taxes	1
Spends enough money at beach (hotel, food, gas, etc.)	1
Total	**17**

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH–MAIL RESPONDENTS	
	No. Responses
NOT SURE SAND REPLENISHMENT WORKS	
Replenishment doesn't work	6
Not sure it works	6
Adding sand is not the answer; protect the dunes	2
Look at other means	1
There will always be a beach; the question is where	1
Total	**16**
DELAWARE RESIDENTS AND PROPERTY OWNERS SHOULD NOT HAVE TO PAY	
Owns beach property	6
We are residents; shouldn't have to pay	6
Property owners should not have to pay	2
Total	**14**
PROPOSED OPTIONS FOR SUPPORTING BEACH REPLENISHMENT	
Federal, state, and local governments should pay	6
Government and user fee should be enough money	2
Responsibility lies with landowner (private and commercial)	2
Merchants should pay	1
Let users pay	1
Total	**12**
EROSION WILL OCCUR NATURALLY	
Let nature take its course	6
Erosion is natural process	4
Replenishment is eventually a losing battle	2
Total	**12**

OTHER REASONS NOT WILLING TO PAY FOR WIDER BEACH--MAIL RESPONDENTS	
	No. Responses
WIDE BEACH ATTRACTS MORE PEOPLE	
More sand means more people	2
Would be willing to pay as last resort	1
Total	4
WOULD BE WILLING TO CONTRIBUTE MORE FOR REPLENISHED BEACH	
Willing to pay to protect beach, wildlife, natural beach	3
Would be willing to pay as last resort	1
Total	4
BEACH WOULD BE TOO WIDE	
Beach too wide	1
Beach would lose its appeal	1
Beach would seem barren if too wide	1
Total	3
MISCELLANEOUS	
Feels previous amount for unnourished beach is adequate	35
Need more information	6
Doesn't like coarseness of sand	1
Not cost-effective in long run, would have to be done too often	1
Assume replenishment will happen no matter who pays	1
Doesn't like quality of water; strong undertow	1
Sand replenishment would create more commercialism, increase costs, and place more control requirements that escalate on the public	1
Thinks money would go elsewhere (boardwalk, vendors, hotels) instead of beach replenishment	1
Total	47

APPENDIX E

OTHER REASONS FOR NOT CONTRIBUTING TO ANNUAL BEACH FUND-- ON-SITE RESPONDENTS	
	No. Responses
LIVE OUT OF STATE	
Not a resident of Delaware	10
Contributes to New Jersey beaches	1
Total	**11**
SHOULD HAVE USER FEE OR ANNUAL CONTRIBUTION, NOT BOTH	
Either user fee or annual contribution	8
Would contribute annually if no user fee	1
Total	**9**
GOVERNMENT SHOULD BE RESPONSIBLE	
Responsibility of state and towns	4
Government should pay through taxes	1
Federal government should pay for disasters	1
Total	**6**
SAND REPLENISHMENT IS A BAD IDEA	
Total	**3**
WOULD NOT USE DELAWARE BEACHES IF HAD TO PAY	
Would go to different beach	2
Would do something else	1
Total	**3**
MISCELLANEOUS COMMENTS	
Against beach fees	1
Nature will take care of beach	1
Not on beach often enough	1
On a limited income	1
Contributing to other funds is more important	1
Would contribute to all East Coast beaches	1
Would contribute if owned property	1
Total	**7**

APPENDIX F

OTHER REASONS FOR NOT CONTRIBUTING TO AN ANNUAL BEACH FUND-- MAIL RESPONDENTS	
	No. Responses
NOT A FREQUENT DELAWARE BEACH USER	
Live out of state, would support that state	8
Doesn't use beach often enough	8
Lives too far away	1
Total	**17**
PROPOSED OPTIONS FOR CONTRIBUTING TO ANNUAL BEACH FUND	
Users and businesses who benefit should pay	4
Taxes should pay for replenishment	3
If there were user fee would not pay annual contribution	3
Prefer annual contribution rather than user fee	1
Would pay if non-fishing vehicles were banned from beach	1
Non-Delawarean--would be willing to pay more for user fee than Delaware resident	1
Total	**13**
NOT SURE SAND REPLENISHMENT WORKS	
Not sure it works	9
Total	**9**
OPPOSED TO CONTRIBUTING TO ANNUAL BEACH FUND	
Limited income; can't afford it	2
Would not contribute just to protect beaches, have to serve meaningful purpose	1
Not sure who should pay and how much it's worth	1
Objects to idea of paying for beach	1
Not sure how much beach is worth	1
Total	**6**
NOT INTERESTED; THERE ARE MORE IMPORTANT THINGS TO SPEND MONEY ON	
Not interested; more important things to spend money on	5
Total	**5**

OTHER REASONS FOR NOT CONTRIBUTING TO AN ANNUAL BEACH FUND--MAIL RESPONDENTS	
	No. Responses
MISCELLANEOUS	
Beach erosion is natural process	3
Survey sounds like a market study	1
Restrict development; this is what causes erosion	1
Age--getting too old to contribute to fund	1
Total	6

APPENDIX G

OPEN-ENDED COMMENTS--ON-SITE RESPONDENTS	
	No. Responses
POSITIVE COMMENTS ABOUT DELAWARE BEACHES	
Enjoy coming to Delaware beaches	14
Delaware beaches are better than Maryland's and New Jersey's	4
Enjoy relaxed family atmosphere	4
Delaware beaches are fantastic	2
Lifeguards are good	2
Enjoys South Bethany because it's not crowded	1
Likes Fenwick Island because no tall buildings	1
Total	**28**
BEACH MANAGEMENT SUGGESTIONS	
Erosion needs to be addressed	3
Everyone should help with beach management	3
Replenish, but no pipes or cranes	1
Beachfront zoning should be stronger	1
Solicit public support by holding public meetings	1
Replace sand only for ecological reasons	1
Only contribute to beaches needing sand replenishment	1
Treat all beaches like state parks	1
Dunes have no effect	1
Bayfront bulkheading is good	1
Dunes should be maintained also	1
Improve management of beachfront lots	1
Responsibility of state and town to replenish	1
Sand replenishment is state responsibility first	1
Need to keep beaches cleaner	1
South Bethany beaches are negatively affected by buildings	1
Management has no effect	1
Delaware should restrict development along beach	1

OPEN-ENDED COMMENTS--ON-SITE RESPONDENTS	
	No. Responses
Need more public rest rooms	1
South Bethany needs concessions and beach rentals	1
Total	**24**
AGAINST USER FEES	
Philosophically against user fees	8
Against user fees	6
Offended by beach user fees in New Jersey	1
Beach user fees are a rip-off	1
User fees will deter tourism	1
Paying for beach makes me mad	1
Will not return if user fee imposed	1
Total	**19**
SAND REPLENISHMENT IS NOT A GOOD IDEA	
Sand replenishment alone is no good	5
Sand replenishment is a bad idea	2
Sand replenishment is futile	2
Federal government should stay out of sand replenishment	1
Sand replenishment should be studied more	1
Total	**11**
SUGGESTED ALTERNATIVES TO DAILY USER FEES	
Include beach user fee within other existing costs	2
Impose $5 user fee for tourist rentals	1
Don't charge businesses or property owners	1
User fee for adults only, not kids	1
User fee on all Delaware beaches is not justified	1
Should have a group rate user fee	1
User fee okay if additional public facilities are provided	1

OPEN-ENDED COMMENTS--ON-SITE RESPONDENTS	
	No. Responses
Yearly family fee is okay	1
Total	**9**
SHOULD HAVE EITHER USER FEE OR ANNUAL CONTRIBUTION	
Would contribute larger annual if no user fee	4
Would contribute annually only if no user fee	2
Wouldn't make annual contribution if user fee imposed	1
Would rather donate annual and reduce user fee	1
User fee should be implemented	1
Total	**8**
PAY THROUGH TAXES	
Should pay through taxes	5
Already pay a tax for beach replenishment	1
Delaware should have a sales tax for sand replenishment	1
Rather pay through increased taxes	1
Total	**8**
NEEDS MORE INFORMATION	
Wants information on sand replenishment in Delaware	3
Needs more information before contributing	1
Not enough information for all the questions	1
Total	**5**
NATURE SHOULD CARE FOR BEACH	
Nature will care for beach	4
Total	**4**
SURVEY METHOD SUGGESTIONS	
Greatly value beach, but survey didn't reflect his true feelings	1
Survey should have asked if own property or not	1
Some survey questions did not fit this beach	1
Total	**3**

OPEN-ENDED COMMENTS--ON-SITE RESPONDENTS	
	No. Responses
BEACHES SHOULD BE FREE	
Total	2
WIDER BEACHES CAUSE INCREASED CROWDING	
Widening made beaches more crowded in Ocean City, Maryland	1
Width would bring more people	1
Total	2
LIKES USING A WIDE BEACH	
Total	2
SUGGESTED ALTERNATIVES TO SAND REPLENISHMENT	
Examine use of offshore reefs	1
Delaware should restrict development along beach	1
Total	2
WOULD DO SOMETHING DIFFERENT	
User fee could make us go to different beach	1
Would go to a different beach if user fee imposed	1
Total	2
ALREADY PAY THROUGH OTHER MEANS	
Already contribute with development recreation fee	1
Total	1
MISCELLANEOUS COMMENTS	
Depends on financial condition of South Bethany whether I'd contribute	1
Just come to beach to enjoy	1
No way to have a secure beach at South Bethany	1
Have a house at beach	1
Beach okay as is	1
Bethany Beach should be as wide as Ocean City, Maryland	1
New Jersey beaches are too wide	1
Owns condo in area; spends two months here	1

OPEN-ENDED COMMENTS--ON-SITE RESPONDENTS	
	No. Responses
Owns property at beach	1
Would contribute if owned property at beach	1
Would contribute to all East Coast beaches	1
Beach replenishment hindered enjoyment in Ocean City, Maryland	1
We are business owners in Bethany Beach	1
Would volunteer to clean up beaches	1
Too far to get to water on New Jersey beaches	1
Tourism depends on wide beaches	1
Only locals would support beach nourishment	1
Delaware should advertise water quality	1
Sand replenishment ruins surfing	1
Would donate money to Maryland, not to Delaware	1
Total	**20**

APPENDIX H

OPEN-ENDED COMMENTS--MAIL RESPONDENTS	
	No. Responses
FUNDS OR FEES SHOULD BE ASSESSED FOR BEACH REPLENISHMENT	
Would pay annual or weekly fee for use of beach (not daily)	23
If replenishment is done, should be paid for by state, county, or town taxes	21
Those who use/benefit the most should pay (owners, merchants)	19
Day trippers/out-of-staters can pay	14
Would pay family user fee, not per person	4
Support sales tax for all users	3
Would pay user fee if beach was nice	3
Doesn't use beach often, but would pay for upkeep	3
Would not pay annual contribution if there was a daily user fee	2
Would pay annually for beach protection	2
Willing to pay for replenishment based on real-estate taxes	1
Would only pay if no other options	1
Public beaches; let public pay	1
State and federal government should pay since revenue brought in by tourism	1
Owners renting property should get charged and direct money to beach preservation	1
Additional federal funds should be made available	1
Renters should pay by week rather than daily (too difficult)	1
Would only pay for beach replenishment at state park like Cape Henlopen	1
Total	**102**
OPPOSED TO BEACH REPLENISHMENT	
Opposed to beach replenishment	18
Not sure replenishment works, look at other options (jetties, reefs, etc.)	14
Can't fight nature, erosion is natural process	13
Preserve beaches as natural resource-protect wildlife	10
Don't widen beaches just to support more people	4
Not familiar enough with beach replenishment	2
Replenish only when necessary	1

OPEN-ENDED COMMENTS--MAIL RESPONDENTS	
	No. Responses
Personally, I like looking at ocean, not lots of sand	1
Total	**63**
FUNDS OR FEES SHOULD NOT BE ASSESSED FOR BEACH REPLENISHMENT	
Oppose beach fees	23
User fees might keep people away and take away others' income	8
Resents/opposed to/not sure about paying for replenishment	7
Locals/DE residents should be exempt from user fees	5
Beaches should be accessible to all (keep fee low, free)	4
Doesn't want tax money spent on beaches; make businesses and residents pay	4
Questions not appropriate for beach homeowners; owner objects to paying	3
Doesn't want DE beaches to be like NJ beaches	2
User fee could put burden on families visiting	2
User fee not indicator of public policy; look at other issues	1
Would not pay penny for beach replenishment to protect houses built where dunes used to be	1
User fees may not maintain beach to a higher level	1
Total	**61**
SUPPORT BEACH REPLENISHMENT OPTIONS	
Please replenish the beaches with sand (replenishment works)	14
Maintain and protect beaches	2
Beach should be maintained and replenished, but don't think it needs to be extremely wide	1
Hope there is a cost-effective way of controlling erosion	1
Total	**18**
MISCELLANEOUS COMMENTS	
Developers are destroying the beaches	12
General comments about survey design	11
Ban disturbing the dunes; dunes help	11
Keep beaches clean, well-maintained--bring in more people	7

OPEN-ENDED COMMENTS--MAIL RESPONDENTS	
	No. Responses
We enjoy the beaches	6
Not familiar with DE beaches--lives out of state	5
All beaches have same problems; federal government needs to get involved	4
Abolish federal flood insurance/insurance too high	3
Doesn't use beach often	3
Develop plan to control growth and limit overcrowding	2
Parking is a problem at some beaches/allow permit parking only	2
Need more information	2
Why have zoning regulations been so lax to allow dunes to be destroyed?	1
No information on U of DE involvement in process or what Sea Grant means	1
No, I don't ever get to DE beaches	1
State gets revenues; towns get problems	1
Set up day care on beach	1
Don't think all DE beaches should be treated the same	1
Allow bulkheading for protection of oceanfront property	1
More advertising would bring in more people and more money	1
For increased revenue, should increase parking, license fees, etc.	1
Total	**77**

APPENDIX I

ON-SITE SURVEY MATERIALS

AND MEAN FREQUENCY RESPONSES

BEACH USER STUDY
FIELD SURVEY INSTRUMENT

Number		Weather/Temp	
Date		Interviewer	
Location		Beach Density	
Time			

HI, I AM WITH THE UNIVERSITY OF DELAWARE, MARINE STUDIES COMPLEX, IN LEWES. TODAY WE ARE DOING SOME RESEARCH ON THE BEACH, AND I WOULD LIKE TO ASK YOU A FEW QUESTIONS. IT SHOULD ONLY TAKE ABOUT TEN MINUTES.

1. Where is your principal home residence? State (1) PA–28%, (2) MD–28%; (3) DE–16%; (4) VA–9% Zip Code ________

2. Are you visiting the beach today as part of a:

8% day visit to this beach community 92% overnight visit to this beach community
- 1% (a) weekend trip
- 75% (b) short vacation (<1 week)
- 13% (c) long vacation (>1 week)
- 8% (d) seasonal resident (June-August)
- 2% (e) other (Specify) Live Year-Round; Live Seasonal

3. What year did you first visit a Delaware ocean beach? Year ______

4. How often have you visited Delaware's ocean beaches since this first visit?

- 69% every year
- 9% every other year
- 8% every 2-5 years
- 4% less often than every 2-5 years 10%–first visit

5. How many days during the course of an average year do you spend on Delaware's ocean beaches?

Days $\bar{x}$ = 16.7

6. What kind of transportation did you use to get to the beach today?

- 43% (a) car/van (How much will you pay for parking?) $\bar{x}$ = $1.21
- 1% (b) park/ride bus (How much did you pay for the park/ride?) $\bar{x}$ = $3.00
- 1% (c) bike
- 54% (d) walk
- 1% (e) other (specify) ________

7. How many hours do you plan to spend on the beach during this particular outing? $\bar{x}$ = 4.7 hours

8. Including yourself, how many people are with you at the beach today? $\bar{x}$ = 4.4

9. **I AM GOING TO READ SOME STATEMENTS ABOUT WHY YOU MIGHT CHOOSE TO VISIT THIS DELAWARE BEACH. PLEASE RATE YOUR LEVEL OF AGREEMENT OR DISAGREEMENT WITH EACH STATEMENT I READ USING THE SCALE ON THE CARD. (1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = UNDECIDED; 4 = AGREE; 5 = STRONGLY AGREE)**

	SD	D	U	A	SA	$\bar{x}$'s
I come to the beach to be with a large number of people.	1	2	3	4	5	2.2
......for solitude (to be alone).	1	2	3	4	5	2.8

......to socialize with family, friends, and others.	1	2	3	4	5	4.1
......to enjoy the visual qualities of the beach scenery.	1	2	3	4	5	4.4
I come to this beach to engage in beach-related activities (swim, surf, etc.)	1	2	3	4	5	4.4
......because it is close to my home or where I am staying.	1	2	3	4	5	4.2
......because there is little or no cost to enjoy it.	1	2	3	4	5	3.9
......because there is adequate parking.	1	2	3	4	5	3.0
......because there are adequate concessions and rentals.	1	2	3	4	5	3.2
......because it has public rest room facilities.	1	2	3	4	5	2.7
......because it is wide enough to enjoy my activities.	1	2	3	4	5	3.9
......because the town keeps the beach clean and attractive.	1	2	3	4	5	4.3

NOW I AM GOING TO READ A FEW STATEMENTS ABOUT BEACH MANAGEMENT AND SAND REPLENISHMENT. AGAIN, RATE YOUR LEVEL OF AGREEMENT OR DISAGREEMENT WITH EACH STATEMENT.

	SD	D	U	A	SA	$\bar{X}$'s
Jetties, groins, and bulkheads are effective at slowing erosion.	1	2	3	4	5	3.4
Sand replenishment should be used to maintain wide beaches.	1	2	3	4	5	3.8
A wide, sandy beach will protect beachfront property and preserve the coastal economy.	1	2	3	4	5	3.9
If I know the beaches are kept replenished with sand, it would give a sense of security to my family and me.	1	2	3	4	5	3.5
The federal government should help support sand replenishment of Delaware's public beaches.	1	2	3	4	5	3.4
State government should help support sand replenishment of Delaware's public beaches.	1	2	3	4	5	4.1
Local government (e.g., the county and coastal towns) should help support sand replenishment of Delaware's public beaches.	1	2	3	4	5	4.1
Everyone who uses or benefits from the beach should help support beach replenishment efforts.	1	2	3	4	5	3.8

10. On a scale of 1-10 (with 10 being perfect), how would you rate the quality of your beach experience today? $\bar{X} = 8.4$

11. Using the crowding scale (refer to card), how would you describe the conditions on the beach today? 1–not at all crowded; 9–extremely crowded $\bar{X} = 4.7$

12. Using the enjoyment scale (refer to card), how has the number of people impacted your enjoyment of the beach today? 1–increased my enjoyment; 9–reduced my enjoyment $\bar{X} = 4.5$

13. NEXT, I WOULD LIKE TO ASK YOU A QUESTION TO HELP US MEASURE THE VALUE SOCIETY PLACES ON THE BEACH. THIS BEACH IS A NATURAL RESOURCE AVAILABLE FOR PUBLIC USE. SINCE THE BEACH IS FREE, THE ONLY WAY WE CAN MEASURE THE VALUE OF THIS PUBLIC BEACH IS TO ESTIMATE IT BY ASKING YOUR WILLINGNESS TO PAY FOR A DAY ON THE BEACH. I DON'T MEAN THAT YOU WOULD REALLY PAY FOR THE BEACH, BUT RATHER, I AM JUST USING THIS FIGURE TO ESTIMATE ITS VALUE.

Would you be willing to pay a per person user fee of (___ \$1, ___ \$2, ___ \$3, ___ \$4, ___ \$5) to use this beach today? 56% Yes; 44% No

What is the maximum you would be willing to pay to use this beach today? \$ $\bar{X}$ = \$3.01 (max. (0's included)

14. If zero (0), which of these reasons best describes why you answered the way that you did?

- 3% a. not enough information
- 9% b. do not want to place a dollar value
- 1% c. object to the way that the question was presented
- 2% d. the figure I gave is what I feel it is worth
- 61% e. already pay through other means
- 13% f. object to method of payment (daily per person user fee)
- 12% g. other (specify) Should be free; would go elsewhere.

15. **(ASK ONLY IF A MONETARY VALUE WAS GIVEN IN QUESTION 13.)**
If a user fee in the amount you indicated was charged, how would that affect the number of visits you typically make to the beach?

- -- more than now. If more, how many more visits? ________
- 76% same as now.
- 24% fewer than now. If fewer, how many fewer visits? ______

16. A MAJOR PART OF THIS STUDY IS TO DETERMINE THE IMPORTANCE OF WIDE BEACHES TO YOU.

Please refer to these two photographs showing two beaches–one without sand replenishment (Photo A) and one with sand replenishment (Photo B). Would you be willing to pay more than the maximum amount previously mentioned (\$___) if the beach you are now using was widened like in Photo B?

30% Yes. If yes, what would you be willing to pay to use the wider beach?
$\bar{X}$ = \$3.70 (maximum) (0's included)

70% No. If no, why not? Specify. Already pay through other means; beach okay as is; width not important; would go elsewhere.

17. **(ASK IF MONETARY VALUE IN #16 IS GREATER THAN 0.)**
If a user fee in the amount you indicated was charged for using the wider ocean beach, how would that affect the number of visits you typically make to the beach?

- 1% more than now. If more, how many more visits? ___
- 68% same as now.
- 31% fewer than now. If fewer, how many fewer visits. ___

18. Which letter on the card best describes your present occupational status? (Refer to card.)

- 65% a. employed full time
- 11% b. employed part time
- 2% c. not employed
- 8% d. retired
- 9% e. full-time homemaker
- 6% f. student
- 1% g. other (specify) ________

19. What is your marital status? 74% Married; 26% Single

20. Record sex. 43% Male; 57% Female

21. (Refer to card.) Which letter on the card best describes your total annual family income?

a. 4% under $10,000
b. 3% $10,000-19,999
c. 6% $20,000-29,999
d. 12% $30,000-39,999
e. 13% $40,000-49,999
f. 30% $50,000-74,999
g. 18% $ 75,000-99,999
h. 14% $100,000 and above

22. What letter on the card best describes the last grade of regular school that you completed?

a. – no school
b. <1% grade school (1-8)
c. 2% some high school (9-11)
d. 17% high school graduate (12)
e. 22% some college (13-15)
f. 31% college graduate (16)
g. 28% post graduate (17+)
h. – no response/refused

23. Ask only if not obvious. How would you describe your racial or ethnic background?

97% White or Caucasian; 2% Black or Negro; 1% Other (specify) American Indian; Asian

24. (Refer to card.) Here is a list of age categories. Would you call off the code number of the category that contains your age?

10-19.....01–3%
20-29.....02–15%
30-39.....03–30%
40-49.....04–31%
50-59.....05–11%
60-69.....06–7%
70+.......07–3%
Refused...08–__

25. Imagine there was a fund established for coastal beach protection against erosion for the sole purpose of protecting Delaware beaches. If you were to make a voluntary once-a-year donation to this fund, even if you did not use the beach, what would be the **MAXIMUM** yearly amount that you would be willing to contribute? This fund would ensure that the beaches would be available for your use, as well as future generations. Keep in mind that this contribution would be in addition to any daily user fees that you might pay. $ $\bar{x}$ = $63.69 (0's included)

26. If zero (0), which of these reasons best describes why you answered the way that you did?

- 11% a. not enough information
- 3% b. do not want to place a dollar value
- 4% c. object to the way question was presented
- 1% d. that is what it is worth
- 34% e. already pay through other means
- 8% f. object to method of payment (annual amount)
- 40% g. other (specify) Would pay annually or daily, not both; not a Delaware resident. (See Appendix.)

27. To help in the design of future questionnaires and in assessing the quality of our data for this study, would you answer the following question? Overall, how understandable did you find the wording of the questions I have asked?

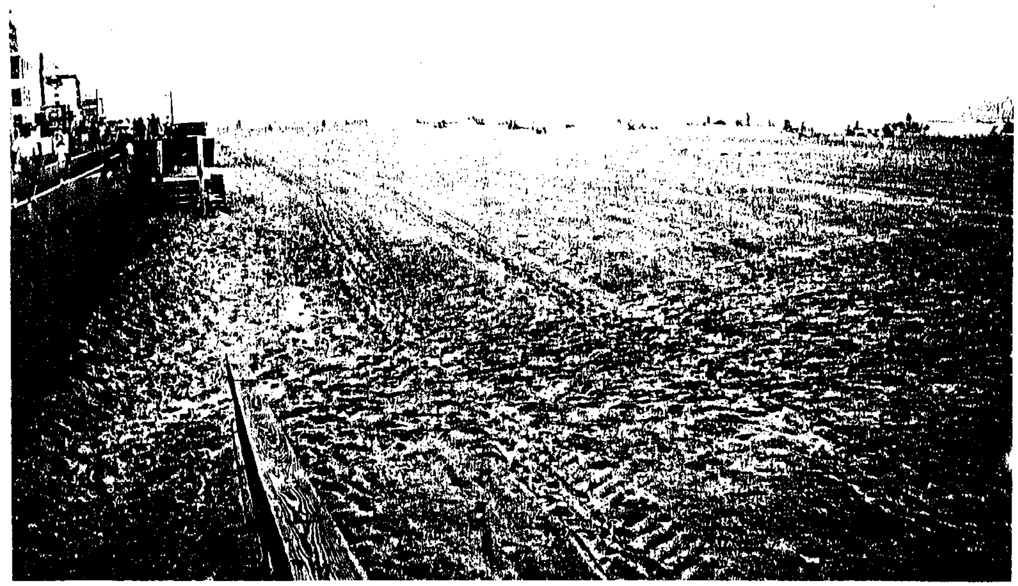
Very clear...2 62%; Clear...1 34%; Moderate...0 3%; Unclear...-1 1%; Very unclear...-2 _

DO YOU HAVE ANY OTHER COMMENTS OR SUGGESTIONS YOU WOULD LIKE TO MAKE REGARDING DELAWARE'S OCEAN BEACHES?

SEE APPENDIX.

PHOTO A—OCEAN BEACH WITHOUT SAND REPLENISHMENT

PHOTO B—OCEAN BEACH WITH SAND REPLENISHMENT



APPENDIX J

MAIL SURVEY MATERIALS

AND MEAN FREQUENCY RESPONSES

University of Delaware
Sea Grant Marine Advisory Service
700 Pilottown Road
Lewes, DE 19958-1298

DELAWARE BEACH STUDY 1993

1. Have you ever visited an ocean beach in Delaware?

   86% Yes   14% No

   Your responses to this survey are still important. Please go to Question 7.

2. When was your last visit to an ocean beach in Delaware? ________ (Year)

3. Please list the number of days during an average year that you spend on each of the following Delaware ocean beaches?

% Who Visited:		$\bar{x}$ Days	% Who Visited		$\bar{x}$ Days
13	Cape Henlopen State Park (Lewes)	6.0	12	South Bethany	33.2
35	Rehoboth Beach	27.7	5	Fenwick Island State Park	17.1
18	Dewey Beach	34.6	14	Fenwick Island	37.1
10	Del. Seashore State Park Beaches	9.4	2	Other Delaware Ocean Beaches	13.0
22	Bethany Beach	29.5		(specify) Indian Beach; North Shores	

   Total Number of Daily Visits in an Average Year ______

4. On the average, including yourself, how many people typically go to the beach with you? $\bar{x}$ = 3.3

5. Do you own residential property in a Delaware ocean beach community?

   50% Yes   50% No

   If yes, is it a 19% primary residence or 81% second home?

   Do you make it available for seasonal or off-season rentals? 23% Yes   77% No

6. WHEN DECIDING TO VISIT THE DELAWARE OCEAN BEACH YOU USE MOST OFTEN (REFER TO QUESTION NO. 3), SEVERAL FACTORS MAY BE OF IMPORTANCE TO YOU. BELOW ARE A LIST OF FACTORS THAT YOU MIGHT CONSIDER WHEN CHOOSING THIS BEACH. PLEASE INDICATE YOUR LEVEL OF AGREEMENT OR DISAGREEMENT TO SHOW THE ROLE EACH FACTOR PLAYS IN YOUR DECISION TO VISIT YOUR FAVORITE DELAWARE OCEAN BEACH.

I CHOOSE THIS BEACH:	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	$\bar{x}$'s
to be with a large number of people	1	2	3	4	5	1.8
to enjoy solitude (to be alone)	1	2	3	4	5	3.5
to socialize with family, friends, and others	1	2	3	4	5	4.2
to enjoy the visual qualities of the beach scenery	1	2	3	4	5	4.4
to engage in beach-related activities (swim, surf, etc.)	1	2	3	4	5	[illegible]
because it is close to my primary residence	1	2	3	4		
because it is close to where I stay on my vacation	1	2	3	4	5	3.3
because there is little or no cost to enjoy it	1	2	3	4	5	3.3

...OOSE THIS BEACH:	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	$\bar{x}$'s
because there is adequate parking	1	2	3	4	5	3.0
because there are adequate concessions and rentals	1	2	3	4	5	2.8
because it has public rest room facilities	1	2	3	4	5	2.7
because it is wide enough to enjoy my activities.	1	2	3	4	5	3.8
because the beach is kept clean and attractive.	1	2	3	4	5	4.2

7. BELOW ARE SEVERAL STATEMENTS ABOUT BEACH MANAGEMENT AND SAND REPLENISHMENT. PLEASE RATE YOUR LEVEL OF AGREEMENT OR DISAGREEMENT WITH EACH OF THESE STATEMENTS.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	$\bar{x}$'s
Jetties, groins, and bulkheads are effective at slowing erosion	1	2	3	4	5	3.4
Sand replenishment should be used to maintain wide beaches.	1	2	3	4	5	3.8
A wide, sandy beach will protect beachfront property and preserve the coastal economy.	1	2	3	4	5	4.0
If I know the beaches are kept replenished with sand, it would give a sense of security to my family and me	1	2	3	4	5	3.6
The federal government should help support sand replenishment of Delaware's public beaches.	1	2	3	4	5	3.5
State government should help support sand replenishment of Delaware's public beaches	1	2	3	4	5	4.0
Local government (e.g., the county and coastal towns) should help support sand replenishment of Delaware's public beaches.	1	2	3	4	5	4.0
Everyone who uses or benefits from the beach should help support beach replenishment efforts	1	2	3	4	5	4.0

THE NEXT QUESTIONS WILL HELP US TO MEASURE THE VALUE SOCIETY PLACES ON THE BEACH. THE BEACH IS A NATURAL RESOURCE AVAILABLE FOR PUBLIC USE. SINCE IT IS FREE, THE ONLY WAY WE CAN MEASURE THE VALUE OF THIS RESOURCE IS TO ESTIMATE IT BY ASKING YOUR WILLINGNESS TO PAY FOR A DAY ON THE BEACH. WE DO NOT MEAN THAT YOU WOULD REALLY PAY FOR THE BEACH, BUT WE WILL SIMPLY USE THIS AMOUNT TO ESTIMATE ITS VALUE.

8. Would you be willing to pay a per person user fee of $ ______ to use a Delaware ocean beach?

   52% Yes   48% No

   What is the maximum amount that you would be willing to pay to use a Delaware ocean beach?

   $ $\bar{x}$ = $2.85 (0's included)

IF YOU PROVIDED A DOLLAR AMOUNT IN QUESTION 8, PLEASE ANSWER 9A. IF YOU ANSWERED ZERO OR PROVIDED NO DOLLAR AMOUNT IN QUESTION 8, PLEASE ANSWER 9B (ANSWER ONLY ONE).

9A. If a user fee in the amount you indicated in Question 8 was charged, how would that affect the number of visits that you typically make to Delaware's ocean beaches?

   3% More than now. If more, how many more visits would you make? ______
   83% Same as now.
   14% Fewer than now. If fewer, how many fewer visits would you make? ______

9B. If you answered zero or did not state a monetary value to Question 8, choose the statement below that best describes your reasons.

- 9% Not enough information.
- 4% Did not want to place a dollar value.
- 6% Objected to the way that the question was presented.
- 2% That is what it is worth.
- 46% Already pay through other means.
- 15% Objected to method of payment (daily per person user fee).
- 18% Other (specify): ______

SINCE THIS SURVEY IS PART OF A LARGER FEASIBILITY STUDY TO ASSESS THE COSTS AND BENEFITS ASSOCIATED WITH SAND REPLENISHMENT OF DELAWARE'S OCEAN BEACHES, IT IS VITAL TO DETERMINE HOW IMPORTANT WIDER BEACHES ARE TO YOU.

10. Please refer to the enclosed xeroxed photographs showing two beaches—one without sand replenishment *(Photo A)*, and one with sand replenishment *(Photo B)*. Would you be willing to pay <u>more</u> than the maximum amount you previously mentioned in Question 8 if Delaware's beaches were widened like the beach in Photo B?

- 21% Yes. If yes, what would be the maximum amount that you would be willing to pay to use the wider beach?
  $ $\bar{x}$=$3.50 maximum. (Please answer Question 11.) (0's included)
- 79% No. If no, why not? (Please specify.) ______

IF YOU DID NOT PLACE A DOLLAR VALUE IN QUESTION 10, PLEASE GO TO QUESTION 12.

11. If a user fee in the amount you indicated in Question 10 was charged for using the wider ocean beach, how would that affect the number of visits you typically make to Delaware's ocean beaches?

- 11% More than now. If more, how many more visits would you make? ______
- 77% Same as now.
- 12% Fewer than now. If fewer, how many fewer visits would you make? ______

THE FOLLOWING INFORMATION WILL HELP OUR RESEARCH STAFF
ANALYZE THE RESULTS OF THE STUDY PROPERLY.

12. Which best describes your present occupational status?

- 58% Employed full-time
- 4% Employed part-time
- ≤1% Not employed
- 4% Other (specify) ______
- 27% Retired
- 4% Full-time homemaker
- 2% Student

13. What is your marital status? 75% Married 25% Single

14. What is your sex? 34% Female 66% Male

15. Which best describes your total annual family income, before taxes?

- 3% Under $10,000
- 4% $10,000 – 19,999
- 6% $20,000 – 29,999
- 12% $30,000 – 39,999
- 12% $40,000 – 49,999
- 18% $50,000 – 74,999
- 14% $75,000 – 99,999
- 32% $100,000 & above

16. Which best describes the last grade of regular school that you completed?

- -- No School
- -- Grade School (1 – 8)
- 2% Some High School (9 – 11)
- 13% High School Graduate (12)
- 16% Some College (13 – 15)
- 25% College Graduate (16)
- 44% Post Graduate (17+)

17. How would you describe your racial or ethnic background?

  95% White or Caucasian
  ≤1% Black or Negro
  4% Other (specify) American Indian; Asian; Egyptian

18. Which best describes your age group?

  1% 10 – 19
  3% 20 – 29
  17% 30 – 39
  23% 40 – 49
  22% 50 – 59
  16% 60 – 69
  19% 70 +

19. To help in the design of future questionnaires and in assessing the quality of our data for this study, overall how did you find the wording and understanding of the questions we have asked?

  32% Very Clear
  46% Clear
  19% Moderate
  3% Unclear
  1% Very Unclear

FINALLY, IT MAY BE WORTH SOMETHING TO YOU TO HAVE DELAWARE'S OCEAN BEACHES REPLENISHED WITH SAND FOR YOUR FUTURE USE, EVEN THOUGH YOU DO NOT INTEND TO USE THEM NOW. IT MAY ALSO BE WORTH SOMETHING TO YOU TO SIMPLY KNOW THE OCEAN BEACHES ARE MAINTAINED FOR FUTURE GENERATIONS AND OTHERS EVEN THOUGH YOU WILL NEVER USE THEM.

20. Imagine there was a fund established for coastal beach protection against erosion for the sole purpose of protecting Delaware beaches. If you were to make a voluntary once-a-year contribution to this fund, even if you did not use the beach, what would be the maximum yearly amount that you would be willing to put toward beach protection to ensure it is available for your use and the use of others?

  $ $\bar{x}$ = 26.60 (0's included) Keep in mind this contribution would be in addition to any daily user fees that you might pay.

21. If you answered zero, or did not state a monetary value to Question 20, choose the statement below that best describes your reasons. (If you placed a monetary value in Question 20, please skip this question.)

  14% Not enough information.
  14% Did not want to place a dollar value.
  5% Objected to the way that the question was presented.
  3% That is what it is worth.
  32% Already pay through other means.
  3% Objected to method of payment (annual amount).
  29% Other (specify): See Appendix.

Do you have any other comments or suggestions you would like to make regarding Delaware's ocean beaches?

SEE APPENDIX.

THAT CONCLUDES THE SURVEY, THANK YOU FOR YOUR COOPERATION.

PLEASE RETURN THE COMPLETED SURVEY FORM
IN THE STAMPED, SELF-ADDRESSED ENVELOPE PROVIDED.

Photo A—Ocean beach without sand replenishment.

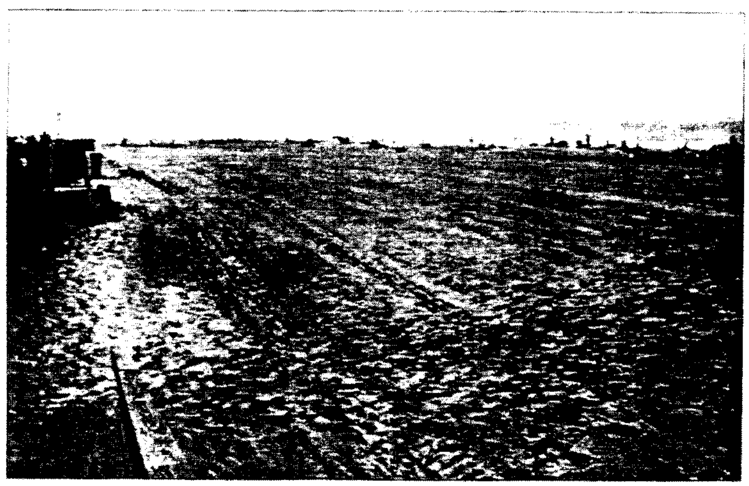


Photo B—Ocean beach with sand replenishment.

UNIVERSITY OF DELAWARE

SEA GRANT
COLLEGE PROGRAM

University of Delaware
Lewes, Delaware 19958-1298
Ph: 302/645- 4236
Fax: 302/645-4007

Fall 1993

Dear Resident:

You have been randomly selected to participate in a study being conducted by the University of Delaware Sea Grant Program to determine people's attitudes about coastal beach protection. This survey is part of a larger feasibility study being initiated by the U.S. Army Corps of Engineers and the Beach Preservation Section of the Delaware Department of Natural Resources and Environmental Control. The objective of the study is to assess the costs and benefits associated with long-term sand nourishment of Delaware's ocean beaches.

Your participation is entirely voluntary, and you may refuse to answer any question. Because only a small number of people are being selected for the study, the participation of each person is extremely important. In completing the questionnaire, keep in mind that most of the questions have to do with your attitudes and opinions, and there are no right or wrong answers.

The information you provide will be kept strictly confidential and will be used only for overall statistical reports. The questionnaire should only take about ten minutes to complete.

When you have completed the survey, please mail it back in the postage-paid return envelope. Thank you for your help.

Sincerely,

J. M. Falk

James M. Falk
Marine Advisory Specialist

Dear Resident:

Last week a questionnaire seeking information on coastal beach protection in Delaware was mailed to you. If you have already completed and returned the questionnaire, please accept our sincere thanks. If not, please do so today.

We are seeking information from people in the region to determine attitudes about nourishing ocean beaches and their willingness to pay for such projects. If the results of the study are to accurately represent the views of the selected sample, it is extremely important that your responses be included.

Thanks again for your help and cooperation.

Sincerely,

J. M. Falk

James M. Falk
Marine Advisory Specialist

UNIVERSITY OF DELAWARE
SEA GRANT
COLLEGE PROGRAM
University of Delaware
Hugh R. Sharp Campus
Lewes, Delaware 19958-1298

Fall 1993

Dear Resident:

About three weeks ago you were sent a questionnaire which is part of a study to determine people's attitudes about coastal beach protection. If you have already returned it, we thank you for your prompt reply. If you have not completed the questionnaire, would you take the time to do so today? It should only take a few moments of your time.

The accuracy of the study depends on the number of questionnaires returned. The information you provide is important because it will help characterize attitudes and feelings of residents from the region on a variety of beach issues that must be addressed by resource managers in the future. Remember, all responses will be summarized and handled in strict confidentiality.

A questionnaire and postage-paid return envelope are enclosed in case you did not receive one or no longer have the first one we sent you.

Thank you again for your interest and cooperation.

Sincerely,

J. M. Falk

James M. Falk
Marine Advisory Specialist

Enclosures

UNIVERSITY OF DELAWARE

SEA GRANT
COLLEGE PROGRAM

University of Delaware
Hugh R. Sharp Campus
Lewes, Delaware 19958-1298

Fall 1993

Dear Resident:

Several weeks ago we sent you a questionnaire seeking your opinions and attitudes about coastal beach protection in Delaware. As of today, we have not received your completed questionnaire.

The large number of questionnaires returned is encouraging. But, whether we will be able to describe accurately how residents living in the region feel about issues related to beach protection and management depends upon you and the others who have not yet responded.

This is the first study of this type conducted on Delawares's ocean beaches. Therefore the results are particularly important to state and federal officials as well as both users and non-users of these important resources. The usefulness of our results depends on how accurately we are able to represent the viewpoints of residents from the entire mid-Atlantic region.

In case our original correspondence did not reach you or was misplaced, a replacement questionnaire and postage-paid envelope are enclosed. May we urge you to complete and return it to us as quickly as possible.

Thank you again for your contribution to the success of this study.

Sincerely,

James M. Falk
Marine Advisory Specialist

Enclosures